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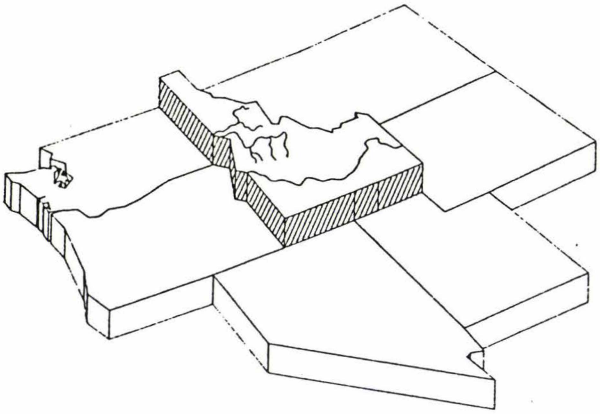
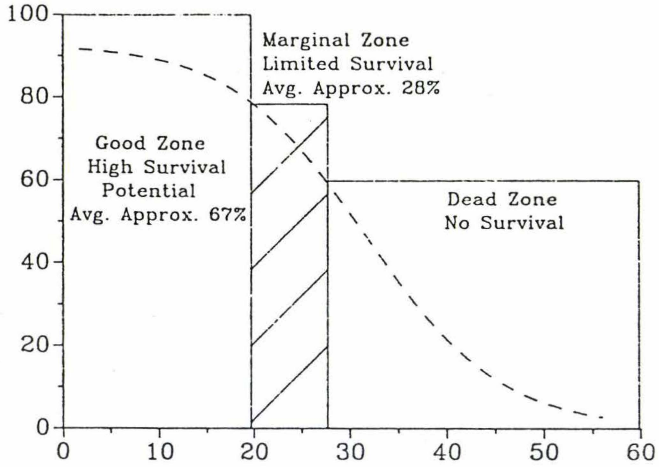
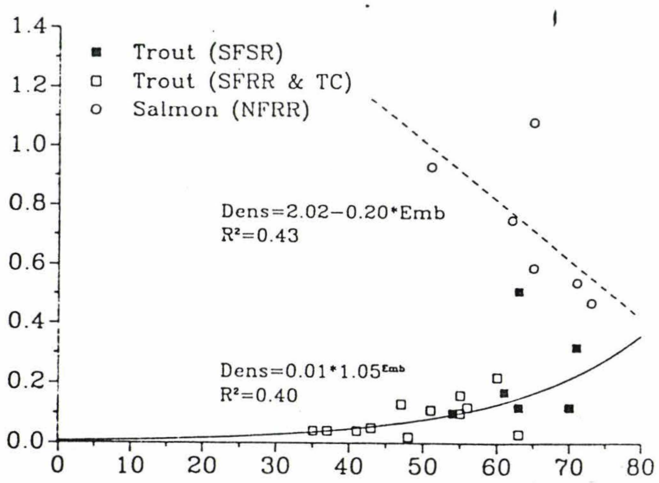
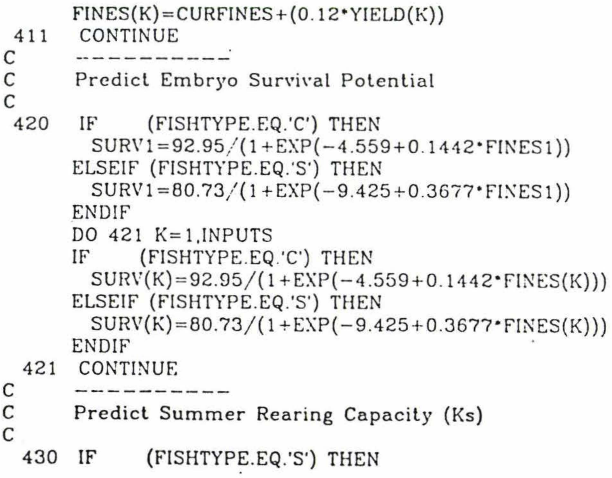
TESTING THE FISHERIES - SEDIMENT RESPONSE MODEL









```
      FINES(K)=CURFINES+(0.12*YIELD(K))
 411   CONTINUE
C      ------------
C      Predict Embryo Survival Potential
C
 420   IF     (FISHTYPE.EQ.'C') THEN
        SURV1=92.95/(1+EXP(-4.559+0.1442*FINES1))
      ELSEIF (FISHTYPE.EQ.'S') THEN
        SURV1=80.73/(1+EXP(-9.425+0.3677*FINES1))
      ENDIF
      DO 421 K=1,INPUTS
      IF     (FISHTYPE.EQ.'C') THEN
        SURV(K)=92.95/(1+EXP(-4.559+0.1442*FINES(K)))
      ELSEIF (FISHTYPE.EQ.'S') THEN
        SURV(K)=80.73/(1+EXP(-9.425+0.3677*FINES(K)))
      ENDIF
  421  CONTINUE
C      -----------
C      Predict Summer Rearing Capacity (Ks)
C
  430  IF     (FISHTYPE.EQ.'S') THEN
```

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EXECUTIVE SUMMARY

Effective forest planning requires the ability to forcast the anticipated effects of resource development activities on all resources potentially affected by the activity. Resource development in national forests often centers around such activities as timber harvest, which can produce large amounts of sediment and have considerable impact on local watersheds. Local watershed disturbance may, in turn, be dispersed a considerable distance downstream, potentially affecting other economically or aesthetically valuable resources.

A team of soil scientists and hydrologists developed a watershed sediment yield model (the R1-R4 model) to predict the potential increase in sediment yields to downstream areas that can result from proposed resource development activities. Fisheries biologists, in turn, have developed the Fisheries-Sediment Response Model (FISHSED-1) to translate expected increases in sediment delivery (as predicted by the R1-R4 model) into potential loss of salmonid fish habitat and consequent reductions in population densities and spawning succes by, pricipally, anadromous chinook salmon and steelhead trout.

Although FISHSED-1 has been used in conjunction with the development of forest plans, it was largely an intuitive model based on the experience and opinions of its authors, and has been inadequately tested under real-world conditions. This study takes the first long, hard look at the ability of FISHSED-1 to predict salmonid habitat and population responses by using actual sediment delivery predictions submitted by National Forest System soil scientists and hydrologists.

By and large, FISHSED-1 was found to be incapable of accurately fulfilling the task for which it was designed. In its simplest application, the model overpredicted trout and salmon populations while underpredicting actual habitat conditions. FISHSED-1 could not accurately predict substrate embeddedness and abundance of subsurface fine sediments from R1-R4 sediment yield predictions. A more complicated application of FISHSED-1 that attempted to incorporate a factor for local sediment storage was no more accurate, and predictions were both higher and lower than actual conditions. Considerable effort was then spent attempting to make the model's functional relationships more accurate, and to develop more sophisticated techniques for incorporating the effects of variable hydrologic conditions, and to propose cautions relevant to the application of any such model.

The principal products provided by this report include the testing results that evaluate the validity of FISHSED-1 when applioed to two separate river systems, a proposed refinement of the model (FISHSED-2), and two new computer programs, one in Fortran 77 and one in BASIC. The FISHSED-2 programs include the original algorithms for FISHSED-1, as well as algorithms that include the actual relationships observed during testing, and an option for inclusion of customized relationships that the user may feel are more appropriate to his or her own situation.

INTRODUCTION

The Fisheries-Sediment Response Model (FISHSED-1) was developed by a committee of fisheries biologists representing several areas of expertise to aid in the decision making process when formulating forest plans. The most recent model attempt first appeared in an unpublished U.S. Forest Service document entitled "Guide for Predicting Salmonid Response to Sediment Yields in Idaho Batholith Watersheds" (Stowell et al. 1983). The model represented the best available estimates of the committe members of the responses of salmonid habitat and local salmonid populations to sediment delivery rates to a specific stream reach. These best available estimates also reflected the limits of the knowledge and experience of the committee of experts that formulated FISHSED-1. To date, however, habitat and population responses predicted by FISHSED-1 remain largely untested under actual field conditions.

Estimates of sediment yield over natural base levels that are predicted by forest hydrologists and soil scientists to be routed (delivered) to a critical stream reach are generated by the R1-R4 Sediment Yield Model (Cline et al. 1981). The predictive functions of the R1-R4 Model are modified to suit the management and watershed conditions of the various national forests or management units. Thus, the Nez Perce National Forest uses a variant referred to as NEZSED, which contains predictive functions appropriate to the specific geoclimatic conditions on their forest, while the Boise National Forest uses a local variant called BOISED; we will refer to all versions generically as the R1-R4 Model. Sediment yield predictions based on the R1-R4 Model represent the "best guesses" of the team of soils and hydrological experts that developed it, with results of some "offsite" research to help determine coefficients within the model.

The R1-R4 estimates of sediment yield for past, present, and proposed forest management activities are used by FISHSED-1 to predict subsequent changes in fish habitat and habitat-induced changes in fish population characteristics. Consequently FISHSED-1 predictions essentially represent expert guesswork based on more expert guesswork; weaknesses in any link of this chain are likely to be compounded as the models are used together, possibly leading to erroneous information for use in forest planning.

While it can be argued that some tools for modeling impacts to assist the planning process are better than no tools, it is equally certain that underestimates of potential watershed and fisheries damages may encourage detrimental land-uses. Conversely, overestimates of sediment delivery and impacts to fisheries may result in economic losses through unnecessary non-consumption of forest resources.

MODEL ASSUMPTIONS

All predictive models are based on a body of underlying assumptions, the validity of which ultimately determine the accuracy of the individual predictions. Consequently, any test of the model also constitutes a test of the model's assumptions. For the FISHSED-1 model, four principal assumptions have been made.

Sediment Disposition Within the Critical Reach

The first and most basic assumption of FISHSED-1 is the assumption that sediment yield predictions made by the R1-R4 Model are accurate. These predictions constitute the principal variable inputs to FISHSED's predictive functions, so the accuracy of FISHSED-1 predictions is limited first by the accuracy of the sediment yield estimates.

One major weakness in the R1-R4 model that has a direct bearing on FISHSED-1 predictions is that the R1-R4 Model predicts increased erosion in response to expected increases in erosion potential of forest soils (including streambanks) in response to alternative land-uses, and uses this prediction to forecast the increase in sediment that will be delivered to a critical stream reach (Cline et al. 1981). Sediment transport through the stream channel and disposition within the critical stream reach has not been adequately studied. In fact, Cline et al. (1981) suggest that the question of sediment disposition is the weakest link in predictions of fishery impacts using R1-R4 Model predictions.

In most forested mountain watersheds under natural conditions, energy available for transporting sediment exceeds sediment supply (Cline et al. 1981). Consequently, most natural sediments will be transported through a critical stream reach rather than being deposited. The amount deposited will approximate the amount that is removed from the reach, and sediment levels in the reach will appear to remain relatively constant. Minor, short-duration increases in sediment delivery will temporarily increase sediment levels in the critical reach, but they will normally be flushed quickly from the system when sediment delivery returns to normal levels.

Once the sediment level exceeds the transport energy available, as might happen during certain land use activities, however, sedimentation in the critical reach will increase more rapidly. Consequently, even declining sediment yields during watershed recovery following cessation of a land-use activity may continue to increase sedimentation levels in the critical reach until sediment delivery falls below some critical threshold delivery level. This process is clear in concept (Figure 1); unfortunately, the value of this threshold delivery level is obscure.

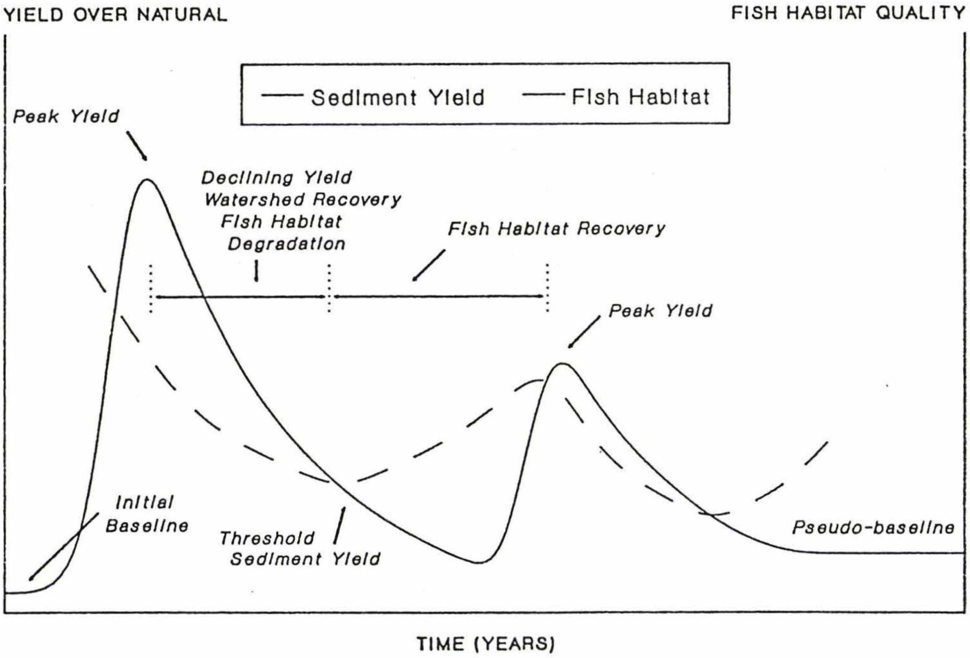

Figure 1.--Conceptual relationships between sediment yield and fish habitat response (adapted from Stowell et al. [1983]).

The FISHSED-1 model contains no provision for dealing with sediment deposition once it is routed to the critical reach. Consequently, application of FISHSED-1 to sediment yield predictions is, at this time, likely to be based on single year or successive single year (increasing annual yields) predictions of sediment yield, a procedure that would be consistent with no storage of excess sediments between entries. Should sediment yields be greater than the threshold level, however, sediments may be retained in the critical reach and FISHSED-1 predictions will underestimate actual sediment levels and overestimate fishery potential.

Limiting Factors

It is widely held among fisheries biologists that the size of fish populations is limited by habitat conditions. While it is undoubtedly true that certain characteristics of the habitat exert more influence over populations than others, and that certain habitat variables can assume values that are lethal to fish, it is less clear whether, under natural or near-natural conditions, fish populations are entirely limited by habitat features. The assumption that habitat characteristics completely limit populations disregards the potential importance of such social regulating factors as territoriality and predation. When one assumes that a single habitat feature can fully predict the status of a fish population, the potential for error increases substantially. However, FISHSED-1 uses functions that attempt to predict population characteristics from one habitat variable.

Embryo Survival and Emergence

Information about the intra-gravel requirements of developing salmonids is currently far from complete. It is widely accepted among fisheries biologists, and well supported in the literature, that excessive amounts of fine sediments in the egg pocket can kill developing embryos by restricting the intra-gravel flow that is needed to deliver dissolved oxygen and remove waste products. Several studies (e.g. McCuddin 1977; Tappel and Bjornn 1983; Irving and Bjornn 1984) have been reported that support the existence of a negative relationship between fine sediments in spawning gravels and embryo survival and fry emergence. Some of the assumptions incorporated in FISHSED-1 need closer examination, however, because their accuracy is crucial to predictive precision.

Field studies of embryo survival and emergence are few, so FISHSED-1 incorporates laboratory-derived relationships of percentage of fine sediments (<6.3mm) to alevin emergence to predict embryo survival from increases in sediment yield (Figure 2). The tacit assumption that such laboratory results can be used to predict real world situations is open to serious debate. The major potential flaw in this assumption is that laboratory studies use a simulated redd with "simplified, unnatural gravel mixtures" (Everest et al. 1987) that may bear little resemblance to natural redds. Even more to the point, Chapman and McLeod (1987) were referring to the laboratory studies used in FISHSED-1 when they stated that "[i]t is always inappropriate to extrapolate such information to field conditions."

Whether relative abundance of fine sediments in the egg pocket alone limits embryo survival and emergence has not been proved under either field or laboratory conditions. Equally confusing is the wide range of particle sizes various researchers consider fine sediments. Which size categories of fines are critical and what developmental phases they impact most are obscure. Clearly, the smaller the material the more likely it is to restrict intra-gravel flow, and the smaller fines may therefore be the most destructive to developing embryos. Fines that are too large to significantly retard intra-gravel flow, however, may still be too small to permit larvae to move upward in the redd and emerge from the gravel. Studies have commonly used sediments of 6.3mm and smaller, 4.8mm and smaller, and 0.85mm and smaller. As mentioned previously, FISHSED-1 is based on studies that used sediments less than 6.3mm in diameter. Sediments of 4.8 to 6.3mm have been counted as gravel rather than fine sediments elsewhere (e.g. Platts et al. 1983). If the fine sediments limiting embryo survival were actually smaller than 4.8mm (or even 0.85mm), then using the percentage of 6.3mm and smaller sediments as a criterion should introduce a large amount of variability into the relationship between fine sediment and survival of embryos.

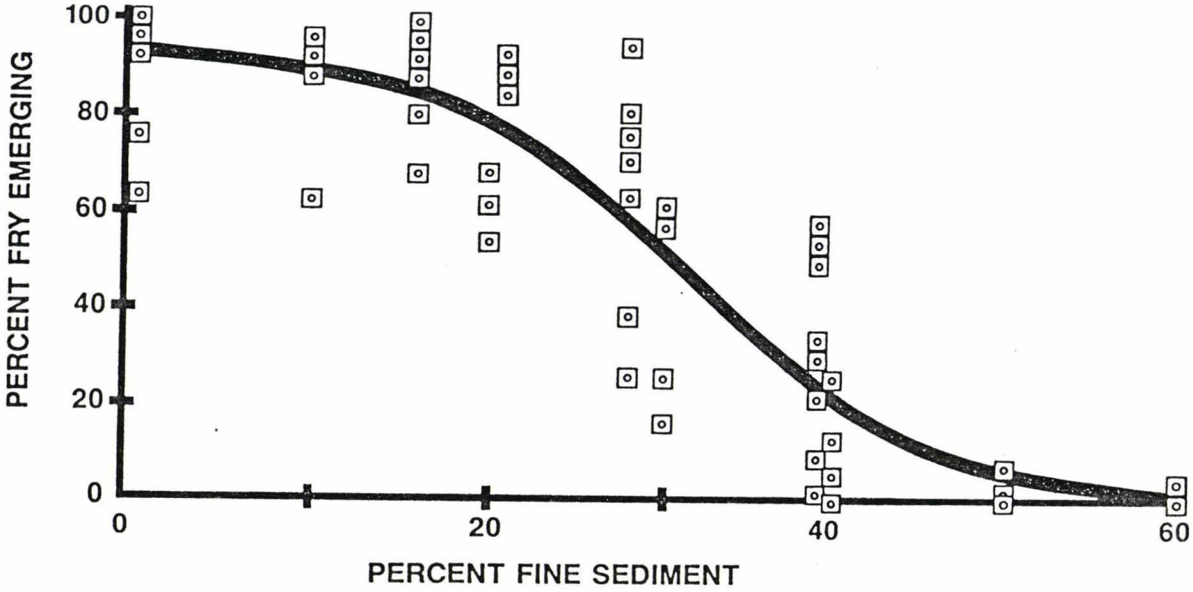

Figure 2.--Predicted relationship between chinook salmon embryo survival and depth fines (from Stowell et al. [1983]).

Winter and Summer Carrying Capacities

Several key assumptions are used by FISHSED-1 to predict changes in winter and summer trout and salmon carrying capacities from changes in aquatic habitat conditions due to predicted changes in sediment delivery. Validity of these assumptions is debatable, but nevertheless crucial for accurate predictions by FISHSED-1.

The relationship between aquatic habitat condition and winter carrying capacity (i.e. the density of fish that can be supported by the habitat through the winter) is presently an active research arena. FISHSED-1 assumes that rubble bottoms of pool habitats are key areas for over-wintering salmonids, and laboratory-derived relationships from Bjornn et al. (1977) (Figures 3 and 4) are used to predict changes in fish density in response to changes in the embeddedness of this habitat. Use of these relationships requires two fundamental assumptions: first, that embeddedness is either the principal factor limiting over-wintering capacity to support juvenile salmonids, or is an accurate surrogate for the actual limiting factor; and, secondly, that laboratory findings can be extrapolated directly to natural situations. Both of these assumptions are debatable.

As embeddedness increases, the interstitial space in the streambottom substrate decreases, thereby reducing the extent and quality of these protective refuges in which salmonid fry can escape winter conditions. There is no obvious reason to question this relationship in a qualitative sense, but there is evidence that embeddedness may not be the only factor that determines winter carrying capacity. Hillman et al. (1987) demonstrated that placing rubble piles in potential in-channel wintering areas initially increased the number of chinook salmon fry that began the winter there; however, the effect of the rubble piles was greatest when located near such areas of cover as undercut successful over-wintering habitat for chinook salmon that remained in small interior rivers with deep pools containing large debris, and for coho salmon with ponds and pools that contained organic cover.

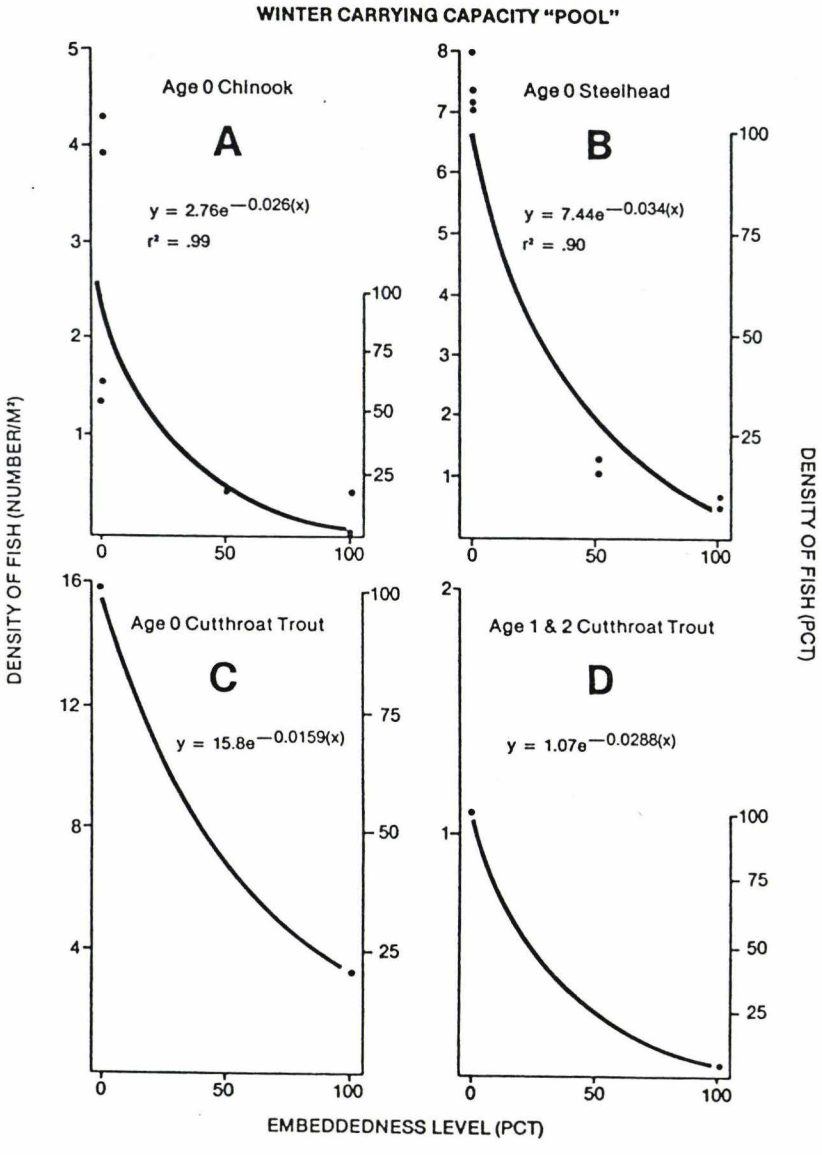

Figure 3.--Predicted relationships between channel embeddedness and winter carrying capacity used by FISHSED-1 (from Bjornn et al. [1977] and Stowell et al. [1983]).

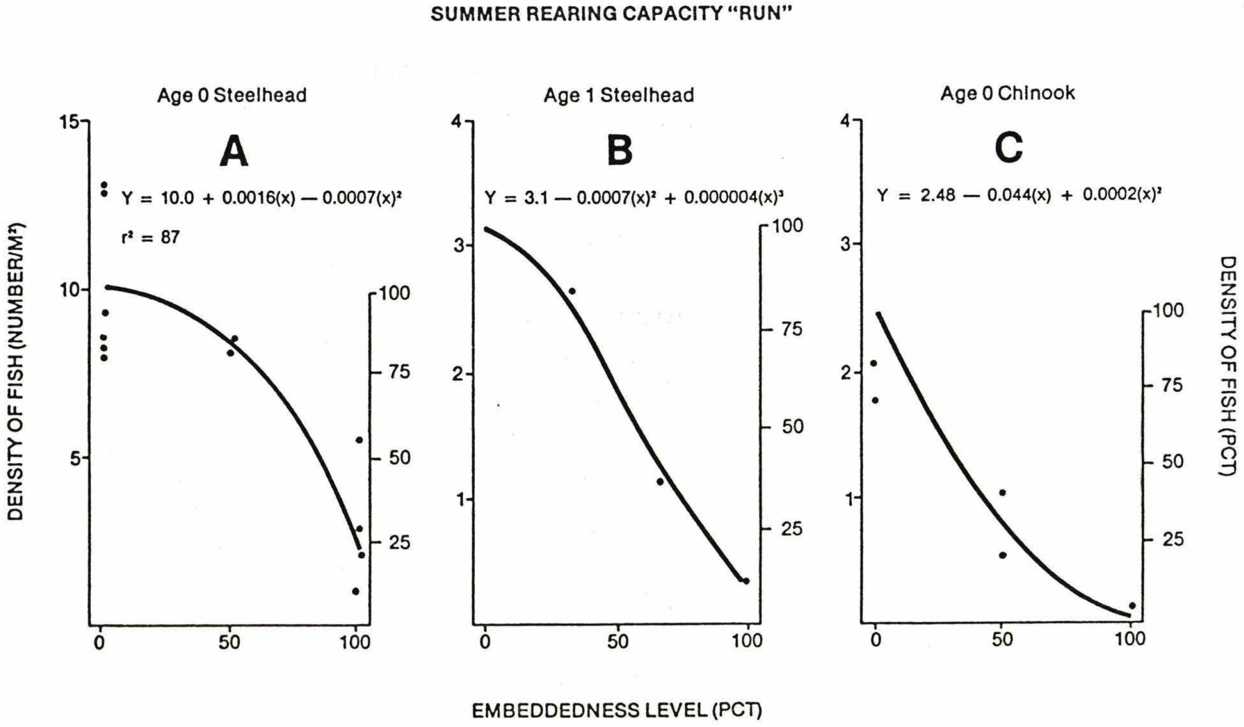

Figure 4.--Predicted relationships between channel embeddedness and summer rearing capacity used by FISHSED-1 (from Bjornn et al. [1977] and Stowell et al. [1983]).

A strong case was made previously for using caution when extrapolating laboratory studies of embryo survival and emergence to field situations; similar cautions are required with predictions of winter carrying capacity based on embeddedness. Chapman and McLeod (1986) devote several pages to criticism of such extrapolation, and have even singled out the use of relationships from Bjornn et al. (1977) in FISHSED-1.
The principal objection of Chapman and McLeod (1987) to using the relationships of Bjornn et al. (1977) in FISHSED-1 is the abnormally high density of fish used in their artificial channels and the correspondingly high densities that the relationships would predict at low embeddedness. Chapman and McLeod (1987) contend that this result may be due to excessively high stocking

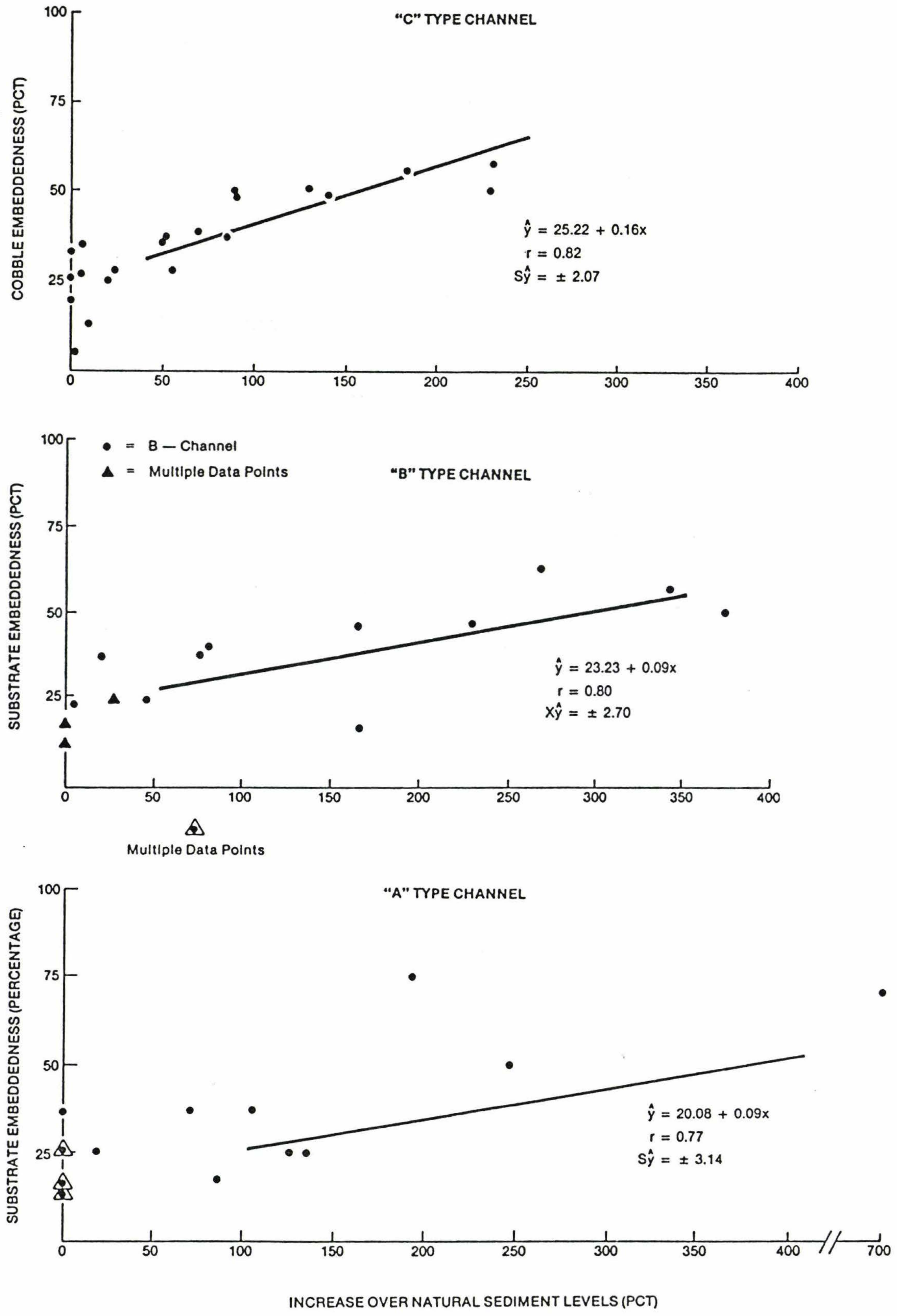

Figure 5.--Predicted relationships between channel embeddedness and sediment yield over natural for A, B, and C channels (from Stowell et al. [1983]).

densities in the artificial channels. Whatever the cause, fish densities predicted by FISHSED-1, in response to virtually any embeddedness level, are too high for even undisturbed streams. Inspection of these relationships (Figure 5) suggests that densities as high as 16 fish/m^2 (age 0 cutthroat trout) are reasonable at 0% embeddedness, falling off to about 4 fish/m^2 at 100% embeddedness. A recent survey of fish densities in western streams (Platts and McHenry 1988) lists no instance of cutthroat trout densities over 2.51 fish/m^2 in either the Pacific of Columbia Forest ecoregions; most densities were much lower.

Use of the embeddedness-fish response curves of Bjornn et al. (1977) in FISHSED-1 was modified to allow determination of percent of natural density as a hedge against the high laboratory densities. Whether these percentages are reliable is unknown and largely untestable. Natural carrying capacities of streams is not well known, so only actual densities can be tested in this study. Monitoring fish densities before and after a land-use activity may allow the percentage change predictions of FISHSED-1 to be tested, but in the meantime we can only extrapolate from observed densities and embeddedness levels and estimate whether the predictions at natural embeddedness seem reasonable.

Prediction of summer rearing capacity is fraught with some of the same dangers as prediction of winter capacity. Stowell et al. (1983) suggests that rubble bottoms of glide habitats are key areas for summer rearing of juvenile salmonids, and FISHSED-1 incorporates embeddedness as the key factor limiting summer rearing capacity. FISHSED-1 relies on relationships between embeddedness and summer rearing capacity that were developed by laboratory studies of Bjornn et al. (1977), and uses the habitat criteria of Burns and Edwards (1985). Use of relationships from Bjornn et al. (1977) requires two fundamental assumptions: first, that embeddedness is the principal factor limiting summer capacity to support juvenile salmonids, or is an accurate surrogate variable; and, second, that laboratory studies can be extrapolated directly to natural situations. Use of criteria and techniques from Burns and Edwards (1985) also requires two fundamental assumptions: first, that habitat fitting their velocity and depth criteria (basically comprising runs or glides) are principal or obligate rearing habitat; and, secondly, that their techniques measure embeddedness well enough to predict fish biomass. All of these assumptions are seriously open to question.

While embeddedness and its potential effects on salmonid eggs, larvae, and fry can be readily grasped in a conceptual sense, measuring it and relating various levels of embeddness to responses in salmonid populations is much more difficult. There are several techniques that are used to measure embeddedness, each incuurring its own unique cost in terms of limitations and human effort requirements. Torquemada and Platts (1988) compared embeddedness measurements obtained using several common techniques, and discuss these considerations at length. More fundamentally, however, there is little in the way of an "objective standard" by which the accuracy of the various measurements of embeddedness can be evaluated.

Stowell et al. (1983) does not specifically state the criteria or techniques that should be used with respect to embeddness measurements when applying FISHSED-1, but its development most likely relied upon the techniques and criteria of Burns (1984) and Burns and Edwards (1985) using hoop embeddeness measurement techniques developed by Kelley and Dettman (1980). The method is very costly in terms of human effort, tends to be restricted to pre-selected instream habitat types rather than being reflective of overall reach conditions, and may pose statistical problems because of the small numbers of independent samples that are frequently taken. While hoop embeddedness offers the apparent security of being a "measured" value rather than one based on observer estimation, the results of Torquemada and Platts (1988) provide little incentive for using it rather than several less costly techniques. Testing, to be discussed later, used measures of embeddedness based on both the hoop and ocular (Platts et al. 1983) techniques, but bases conclusions principally upon the latter.

Channel Classification

The FISHSED-1 model relies on channel classifications following Collotzi (1974), Espinosa et al. (1981), and Rosgen and Silvey (1980). These classifications stratify stream channels into 3 broad categories based on width, depth, velocity, discharge, gradient, bed roughness, bed material particle size, and sinuosity. For FISHSED-1, three principal channel types are recognized: A-channels, with high gradients, narrow, well incised "v"-shaped canyons; B-channels, with moderate gradients, broad, moderately incised "v"-shaped canyons; and C-channels, with low gradients, broad, poorly incised channels. (See Appendix C of Stowell et al. [1981] or the cited references for more thorough descriptions of channel types.)

The significance of channel classification to FISHSED-1 lies in the differences in sediment transport and storage in the different channel types. Sediment transport competence decreases with channel type, with A-channels being the most competent and C-channels the least. Consequently, sediment yields over natural from surrounding watersheds will probably be felt most strongly in C channels, which also happen to be the most likely channels to support anadromous fish spawning areas. The FISHSED-1 model uses calculated relationships between embeddedness and sediment delivery over natural (Figure 5) and between depth fines and sediment delivery over natural (Figure 6) to predict in-channel fish habitat responses to increases in sediment yield.

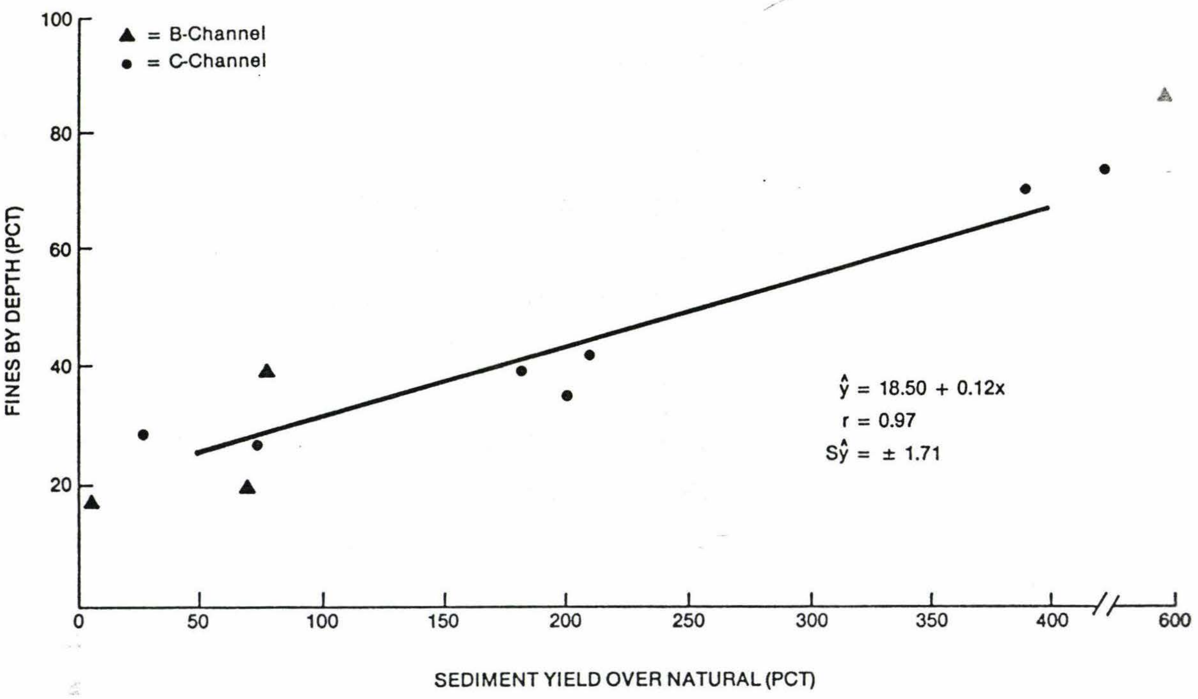

Figure 6.--Predicted relationships between depth fines and sediment yield over natural for B and C channels (from Stowell et al. [1983]).

Although the functional relationships used reflect observational data, it is not clear whether they incorporate cumulative effects of sustained above-natural sediment yield or whether they are merely point estimates. This consideration is analogous to that discussed for sediment disposition and is a potential source of error.

The accuracy with which FISHSED-1 can predict changes in embeddedness and depth fines is obviously dependent on the validity of these functional relationships. These relationships can be directly tested by comparing model predictions with actual habitat conditions.

TESTING AREAS

The FISHSED-1 model was tested in two disjunct drainages in the Northern Rocky Mountain Physiographic Province (Fenneman 1931) in the state of Idaho (Figure 7). Study areas were established on the North Fork of Red River (NFRR), the South Fork of Red River (SFRR), on Red River (RR) below the confluence of NFRR and SFRR, and on Trapper Creek (TC), a tributary of SFRR, and at 4 locations on the South Fork Salmon River (SFSR) at Upper Stolle Meadows (USM), Lower Stolle Meadows (LSM), Poverty Flat (PF), and Krassel Hole (KH); an additional study area was located in Tyndall Meadows (TM) on Johnson Creek, a major SFSR tributary (Figure 7).

In most cases, each study area contained a pair of study sites to allow replication; the only exception was KH. The replicates were designated upper or lower in relation to streamflow; thus, SFRR contained two sites, Upper SFRR (USFRR) and Lower SFRR (LSFRR). Throughout this document, sites will be referred to by their acronyms (Figure 7).

Figure 7.--Location of the study areas used for testing the Fisheries-Sediment Response Model.

METHODS

Model Application

Methods for applying sediment yield predictions to FISHSED-1 are at best vaguely stated in Stowell et al. (1983). It is clear that a single significant actual or planned sediment increasing event or several such events in succession will incur responses in fish habitat conditions when excess sediment is delivered to the critical reach. While anticipated "instantaneous" responses of fish habitat in the critical reach to such impacts can be readily predicted by the model, the effects of declining (but still in excess of natural or post-event baseline levels) yields while the watershed recovers from development activities and the mechanics of fish habitat recovery remain unclear. Consequently, two divergent approaches to using the model have been employed in the following analysis. These approaches were: (1) single or successive single entry evaluation without cumulative effects ("non-cumulative approach"), and (2) single or successive single entry evaluation with cumulative effects ("cumulative approach").

Non-Cumulative Approach

The non-cumulative approach assumed that a sediment-producing event on the watershed was essentially independent of succeeding events of lesser magnitude; consequently, it ignored any consequences relating to watershed recovery. Thus, if a sediment producing event of some magnitude were followed by an event of greater magnitude, both events were considered to have contributed to off-site fish habitat degradation. If, however, the first event were followed by an event of lesser magnitude, only the first event would have been considered to have contributed to downstream habitat degradation. If streams can adequately flush sediments routed to them from the first event before excess sediments are delivered by the succeeding event, the assumption would be valid. This is the simplest application of FISHSED-1, and the one most likely to be routinely employed.

Cumulative Approach

The cumulative approach assumed that sequential sediment yield events were not independent until a developed or pseudo-baseline yield was developed. This approach incorporated the effect of delayed watershed recovery, though it continued to ignore any effects of aquatic habitat recovery. Thus, the two scenarios described above would each have had two events that contributed to downstream degradation. If streams could not flush themselves between successive events, even if succeeding events were smaller than preceding events, then this assumption would be valid. This approach is somewhat more complicated than the non-cumulative approach, but not excessively so. This approach intuitively seems more reasonable than the non-cumulative approach, because sediment deposited by watershed events may be stored in certain low gradient reaches despite their rapid removal from higher gradient reaches.

Physical Habitat Relationships

Once FISHSED-1 was used to generate predictions of fish habitat and population response to predicted increases in sediment delivery, the predictions were evaluated in light of actual field data. Actual field conditions were then used to derive more realistic coefficients for use in the model´s predictive routines.

Model Refinement

The two approaches to model application described previously are the only ways in which an inexperienced user would be likely to use FISHSED-1, and probably represent the manner in which the design committee intended it to be used. They seem, however, to be rather naive approaches to predicting the responses of fish populations and habitat to watershed development, and some more sophisticated approaches are needed. Some additional information on actual relationships between known habitat conditions and fish populations is now available to improve the predictive ability of the model.

Delayed Approach

The delayed approach to model refinement attempted to account for delayed aquatic habitat recovery in conjunction with the basic non-cumulative approach. Thus, predictions of fish population and habitat responses will not be immediately negated after a sediment increasing activity ceases, and some residual effects will be incorporated in FISHSED´s predictions. While aqautic habitat recovery is only poorly understood and, for Idaho Batholith streams, has been studied at length only on the South Fork Salmon River (Platts et al., in press), some function modeling recovery would seem to be desireable. Consequently, since Stowell et al. (1983) state that the SFSR recovery rate was about 12% annually, we have used this figure in examining potential model refinements.

Declining Approach

The declining approach combined the cumulative approach with the anticipated consequences of aquatic habitat and watershed recovery. Aquatic habitat recovery following heavy accumulation of instream sediment is poorly understood, as are the effects of declining but above normal yields during watershed recovery. In the long-term, instream sediment should be in balance with sediment delivery. Catastrophic inputs of sediment, or successive land-use inputs well above natural levels should increase sediment accumulation in the critical reach. Following cessation of these events, sediment delivery is reduced and the streambed should begin recovering. Recovery processes on Idaho Batholith streams have only been carefully monitored on the South Fork Salmon River (SFSR) (Platts et al. in press). Recovery was simulated by decrementing the difference between the peak sediment yield and the developed or pseudo-baseline by 20% annually over a 5-year period to determine what we have called an "effective yield".

FISHSED-2

The physical habitat-sediment yield relationships that were developed for testing the FISHSED-1 predictions were used to formulate new predictive functions for FISHSED-2, the enhanced fisheries-sediment response model. The changes were incorporated in the coefficients of the depth fines-embryo survival and the embeddedness-fry density functions to better reflect actual stream conditions rather than laboratory conditions.

MODEL TESTING

Non-Cumulative Approach

Trapper Creek

Using the non-cumulative approach, all FISHSED-1 physical habitat and fish density predictions for TC except depth fines appear unrealistic (Table 1).

Table 1.--Comparison of actual cutthroat trout population densities and habitat conditions with FISHSED-1 predictions, (non-cumulative approach) Trapper Creek, Nez Perce National Forest, Idaho. All values except fish carrying capacities and densities are expressed as a percentage; carrying capacities and densities are expressed as fish/m2.

	Predicted Values			Observed Values			
				Embeddedness			
Year	Embedded	Fines	Summer Rearing Capacity	Ocular	Hoop	Fines	Summer Density
				-- Upper Trapper Creek --			
1984	24.0	19.6	9.64	60 [1]	14.5	21	0.22
1985	24.1	19.7	9.63	55.6	34.5	NA	0.12
1986	23.9	19.5	9.64	54.8	NA	NA	0.10
Avg.	24.0	19.6	9.64	56.8	24.5	21	0.15
				-- Lower Trapper Creek --			
1984	24.0	19.6	9.64	55 [1]	14.5	21	0.16
1985	24.1	19.7	9.63	47.0	34.5	NA	0.13
1986	23.9	19.5	9.64	50.7	NA	NA	0.11
Avg.	24.0	19.6	9.64	50.9	24.5	21	0.13
Comb. Avg.							

[1] Converted from older embeddedness ranking scale.

Stream ocular embeddedness was much higher than predicted embeddedness, with an average difference of 124%. Even hoop embeddedness for 1985 was 75% higher than the corresponding FISHSED-1 prediction.

Depth fines were only measured in 1984, and actual values were quite similar to predicted values.

Actual summer cutthroat trout fry densities were far below the steelhead fry densities predicted by FISHSED-1. The model predicted steelhead fry capacities to range from 9.63 to 9.64 fish/m^2, or 96.3 to 96.4% of full capacity. Since Trapper Creek contains only cutthroat trout, which are not considered in FISHSED-1 with respect to summer densities, we have to assume that steelhead and cutthroat fry are similarly responsive to embeddedness; given the similarities of the two species, this assumption seems adequate in this case. Actual densities were 0.12 and 0.11 fish/m^2 for 1985 and 1986, respectively, nearly *two* ***orders*** of magnitude below predicted densities. Platts and McHenry (1988) report trout densities from several Idaho streams, and averaging their reported values yields a density of 0.10 fish/m^2, approximately the densities observed on Trapper Creek.

South Fork Red River

Actual aquatic habitat conditions for the SFRR site were generally inconsistent with FISHSED-1 predictions (Table 2), but the disparities were generally less than for TC.

Ocular embeddedness ranged from 43% (USFRR, 1986) to about 163% (LSFRR, 1984) greater than FISHSED-1 predictions. Restricting ocular embeddedness measures to glide habitat had little effect on the magnitudes of the differences between actual and predicted levels. Hoop estimates were closer at 12% lower and 37% greater than FISHSED-1 predictions for 1984 and 1985, respectively. Again, however, the hoop estimate that was closer to the model prediction was based on only one hoop in an unspecified habitat type; it should therefore be viewed with caution. In addition, the 1985 hoop estimates undersampled pool habitats (only one pool sampled); including the single pool sample twice in the overall average would raise the average to 39.2%, very close to the corresponding ocular measurement. Ocular embeddedness declined in both SFRR sites from 1984 to 1986.

The single core sample estimate of depth fines (1985) was 85% greater than predicted by FISHSED-1.

Table 2.--Comparison of actual fish habitat conditions and population densities with FISHSED-1 model predictions (non-cumulative approach), South Fork Red River, Nez Perce National Forest, Idaho. All values except fish carrying capacities are expressed as a percentage; carrying capacities are expressed as fish/m2.

	Predicted Values				Actual Values						
			Summer Rearing Cap.		Embeddedness			Summer Fish Density			
Year	Embedded	Fines	Steel.	Chin.	Ocular	Hoop	Fines	Steel.	Cutt.	Chin.	Total
-- Upper South Fork Red River --											
1984	24.2	19.8	9.63	1.53	48 [1]	21.4	NA	0.00	0.02	0.13	0.15
1985	24.2	19.8	9.63	1.53	41.2	33.2	36.7	0.01	0.04	0.00	0.05
1986	24.2	19.8	9.63	1.53	34.7	NA	NA	0.01	0.04	0.00	0.05
Avg.	24.2	19.8	9.63	1.53	41.3	27.3	36.7	0.01	0.03	0.04	0.08
-- Lower South Fork Red River --											
1984	24.2	19.8	9.63	1.53	63 [1]	21.4	NA	0.00	0.03	0.04	0.07
1985	24.2	19.8	9.63	1.53	42.9	33.2	36.7	0.01	0.06	0.01	0.08
1986	24.2	19.8	9.63	1.53	37.2	NA	NA	0.00 [2]	0.04	0.00	0.04
Avg.	24.2	19.8	9.63	1.53	47.7	27.3	36.7	0.00	0.04	0.02	0.06
Comb. Avg.	24.2	19.8	9.63	1.53	44.5	27.3	36.7	0.01	0.04	0.03	0.07

[1] Converted from older embeddedness ranking scale.
[2] One fish collected.

Summer carrying capacities for steelhead trout fry predicted by FISHSED-1 were more than *two orders* of magnitude greater than actual steelhead trout fry densities. In fact, steelhead and cutthroat fry together made up, on average, only 0.6% of the FISHSED-1 prediction for steelhead fry; even with chinook added to the total, actual densities were far below FISHSED-1 predictions. Since cutthroat should exhibit higher densities (according to response curves in Appendix E of Stowell et al. (1983)), over-prediction by the model may be even more severe than the data suggest at first glance. Average density for 2 rainbow trout streams reported by Platts and McHenry (1988) was 0.11 fish/m^2, 38 and 120% greater, for 1985 and 1986, respectively, than average ensities observed on SFRR.

Chinook occurred sporadically in the SFRR sites, but when present they were generally found to be at a densities about one order of magnitude below FISHSED-1 predictions. The really interesting thing is that their average density was higher than for either steelhead or cutthroat, both of which FISHSED-1 always predicts to be more abundant.

North Fork Red River

In the NFRR study area, FISHSED-1 predictions were invariably lower than actual habitat conditions (Table 3).

Ocular embeddedness estimates ranged from 85% (1986) to 166% greater than predicted values. Hoop estimates were closer to predicted values than ocular estimates, but they did not represent all habitat types (1984 types were unspecified while 1985 samples did not include any pool). Ocular embeddedness levels in glide habitats only were closer to FISHSED-1 predictions (89 and 71% different for 1985 and 1986 [averaged for both study sites], respectively) and were within 10 percentage points of hoop estimates. Both embeddedness measurement techniques were lower in 1985 than in 1984, and ocular embeddedness declined further in 1986; the rate of decline in ocular embeddedness was 7.5% per year.

Table 3.--Comparison of actual fish habitat conditions and population densities with FISHSED-1 model predictions approach), (non-cumulative North Fork (Upper) Red River Nez Perce National Forest, Idaho. All values except carrying capacities are expressed as percentage; carrying capacities are expressed as fish/m2.

	Predicted Values						Actual Values						
			Rearing Capacity				Embeddedness			Fish Density			
					Chinook							Chinook	
Year	Embed.	Fines	Steel. Summer	Cutt. Summer	Winter	Summer	Ocular	Hoop	Fines	Steel. Summer	Cutt. Summer	Winter	Summer
-- Upper North Fork Red River --													
1984	27.4	20.2	9.52	NA	1.47	2.39	65 [1]	42.0	42.4	0.00 [2]	0.01	0.15	0.59
1985	27.4	20.2	9.52	NA	1.47	2.39	62.0	36.5	37.7	0.00	0.01	0.09	0.75
1986	27.4	20.2	9.52	NA	1.47	2.39	50.7	NA	NA	0.03	0.01	NA	0.93
Avg.	27.4	20.2	9.52	NA	1.47	2.39	59.2	39.3	40.1	0.01	0.01	0.12	0.76
-- Lower North Fork Red River --													
1984	27.4	20.2	9.52	NA	1.47	2.39	73 [1]	42.0	42.4	0.01	0.02	0.15	0.47
1985	27.4	20.2	9.52	NA	1.47	2.39	71.0	36.5	37.7	0.04	0.00 [3]	0.09	0.54
1986	27.4	20.2	9.52	NA	1.47	2.39	64.6	NA	NA	0.01	0.02	NA	1.08
Avg.	27.4	20.2	9.52	NA	1.47	2.39	69.5	39.3	40.1	0.02	0.01	0.12	0.70
Comb. Avg	27.4	20.2	9.52	NA	1.47	2.39	64.4	39.3	40.1	0.02	0.01	0.12	0.73

[1] Converted from older embeddedness ranking scale.
[2] One fish collected.
[3] Two fish collected.

Measured amounts of depth fines were 110 and 87% greater than FISHSED-1 predictions in 1984 and 1985, respectively; like embeddedness, fine sediments declined (by 11.1%) between 1984 and 1985.FISHSED-1 predictions of chinook fry summer rearing capacity were extremely high compared to actual salmon densities. The greatest difference (LNFRR, 1984) was a prediction 409% higher than actual, but even the closest prediction (LNFRR, 1986) was 121% too high.

Chinook densities are, however, far higher than observed densities of steelhead and cutthroat trout fry in the other Red River drainage study areas, a situation that contradicts the densities expected from the response curves in Appendix E of Stowell et al. (1983). Steelhead and cutthroat trout occurred in the NFRR sites at densities about *two orders* of magnitude below capacities predicted by FISHSED-1.

Red River

FISHSED-1 predictions were invariably lower than observed habitat conditions (Table 4).

Ocular embeddedness ranged from 79% (URR, 1985) to 137% (LRR, 1986) higher than model predictions. Ocular measurements of embeddedness in glide habitat alone (43.5 and 55.1% for 1985 and 1986 [averaged for both sites], respectively) were closer to model predictions, though they were within 10 percentage points of overall reach estimates. The only available hoop measurement of embeddedness (1985) was higher than model predictions by 100%, but included habitats not conforming to the criteria of Burns and Edwards (1985). When only samples fitting these criteria were considered, hoop embeddedness was estimated at 32.9%, only 20% greater than the FISHSED-1 value.

Actual abundances of depth fines exceeded FISHSED-1 values by 52 and 77% in 1984 and 1985, respectively.

Table 4.--Comparison of actual fish habitat conditions and population densities with FISHSED-1 model predictions (non-cumulative approach), Red River (below Red River R.S.), Nez Perce National Forest, Idaho. All values except fish densities and carrying capacities are expressed as a percentage; carrying capacities are expressed as fish/m2.

	Predicted Values		Actual Values		
			Embeddedness		
Year	Embedded	Fines	Ocular	Hoop	Fines
		-- Upper Red River --			
1984	27.4	20.2	58	NA	30.7
1985	27.4	20.2	49.0	54.8	35.8
1986	27.4	20.2	64.1	NA	NA
Avg.	27.4	20.2	57.0	54.8	33.3
		-- Lower Red River --			
1984	27.4	20.2	65	NA	30.7
1985	27.4	20.2	51.1	54.8	35.8
1986	27.4	20.2	60.8	NA	NA
Avg.	27.4	20.2	59.0	54.8	33.3

Upper Stolle Meadows

Based on the sediment yield input predictions of BOISED model (the Boise National Forest version of the R1-R4 model), FISHSED-1 predictions of embeddedness in the Upper Stolle Meadows study sites were far to low (Table 5). Actual ocular embeddedness exceeded model predictions by 122 (Upper Site, 1986) to 200% (Upper Site, 1984). In addition, embeddedness declined in the Upper Site by 26% during the study period, which could not be accounted for by either FISHSED-1 or the R1-R4 model.

Table 5.--Comparison of actual bull trout population densities and habitat conditions with FISHSED-1 model predictions (non-cumulative approach) for steelhead trout, Upper Stolle, Upper Site, Boise National Forest, Idaho. All values except fish densities and carrying capacities are expressed as a percentage; carrying capacities are expressed as a fish/m2.

	Predicted Values			Actual Values			
				Embeddedness			
Year	Embedded	Fines	Summer Rearing Capacity	Ocular	Hoop	Fines	Summer Density
			-- *Upper Site* --				
1984	23.3	18.6	9.8	70 [1]	NA	NA	0.12
1985	23.3	18.6	9.8	54.1	NA	NA	0.10
1986	23.3	18.6	9.8	51.7	NA	NA	NA
Avg.	23.3	18.6	9.8	58.6	NA	NA	0.11
			-- *Lower Site* --				
1984	23.3	18.6	9.7	63 [1]	NA	NA	0.12
1985	23.3	18.6	9.7	61.0	NA	NA	0.17
1986	23.3	18.6	9.7	65.9	NA	NA	NA
Avg.	23.3	18.6	9.7	63.3	NA	NA	0.15
Comb. Avg.	23.3	18.6	9.7	61.0	NA	NA	0.13

[1] Converted from older embeddedness ranking scale.

Fines data are not yet available for these sites.

FISHSED-1 was not originally designed to include bull trout, the only indigenous species in the Upper Stolle Meadows area. Although this portion of the SFSR supports a healthy population of bull trout, predictions of summer fry density using FISHSED-1's steelhead trout relationships were much higher than actual trout densities. The FISHSED-1 prediction of 9.7 fish/m^2 was an astounding 7,362% higher than the actual combined average trout density of 0.13 fish/m^2 in the Upper Stolle Meadows sites.

Lower Stolle Meadows (Table 6)

These data are not yet available.

Poverty Flat (Table 7)

These data are not yet available.

Krassel Hole (Table 8)

These data are not yet available.

Tyndall Meadows

FISHSED-1 predictions of embeddedness in the Tyndall Meadows study sites were far too low (Table 9). Actual ocular embeddedness was 167 and 198% higher in the upper and lower sites, respectively, than predicted by FISHSED-1.

Data on depth fines are not available for these sites yet.

FISHSED-1 was not originally designed to include brook trout, the dominant species in the Tyndall Meadows area. Although this portion of the Johnson Creek supports a healthy population of brook trout, predictions of summer fry density using FISHSED-1's steelhead trout relationships were much higher than actual trout densities. The FISHSED-1 prediction of 9.6 fish/m^2 was a whopping 2,186% higher than the actual combined average trout density of 0.42 fish/m^2 in the Tyndall Meadows sites.

Table 9.--Comparison of actual fish population densities and habitat conditions embryo survival, and rearing capacity with FISHSED-1 model predictions (non-cumulative approach), Upper Tyndall Meadows, Boise National Forest, Idaho. All values except fish densities and carrying capacities are expressed as a percentage; carrying capacities are expressed as a fish/m2.

	Predicted Values			Actual Values			
			Summer Rearing	Embeddedness			Summer
Year	Embedded	Fines	Capacity	Ocular	Hoop	Fines	Density
			-- Upper Tyndall Meadows --				
1984	23.7	19.1	9.6	NA			NA
1985	23.7	19.1	9.6	63.2			0.51
1986	23.7	19.1	9.6	NA			NA
Avg.	23.7	19.1	9.6	63.2			0.51
			-- Lower Tyndall Meadows --				
1984	23.7	19.1	9.6	NA			NA
1985	23.7	19.1	9.6	70.7			0.32
1986	23.7	19.1	9.6	NA			NA
Avg.	23.7	19.1	9.6	70.7			0.32
Comb. Avg.	23.7	19.1	9.6	70.7			0.42

Although a few resident rainbow trout occur in this portion of Johnson Creek, there presence is so irregular that they were excluded them from this analysis.

Summary

Non-Cumulative Approach

Trapper Creek

For TC, the cumulative approach may provide better predictions of conditions than the the non-cumulative application of FISHSED-1 (Table 10).

Table 10.--Comparison of actual cutthroat trout population densities and habitat conditions with FISHSED-1 predictions (cumulative approach), Trapper Creek, Nez Perce National Forest, Idaho. All values except fish densities and carrying capacities are expressed as a percentage; carrying capacities and densities are expressed as fish/m2.

	Predicted Values			Actual Values			
			Summer Rearing	Embeddedness			Summer
Year	Embedded	Fines	Capacity	Ocular	Hoop	Fines	Density
			-- Upper Trapper Creek --				
1984	40.8	41.9	8.90	60[1]	14.5	21	0.22
1985	42.6	44.4	8.80	55.6	34.5	NA	0.12
1986	43.5	45.6	8.75	54.8	NA	NA	0.10
Avg.	42.3	44.0	8.82	56.8	24.5	21	0.15
			-- Lower Trapper Creek --				
1984	40.8	41.9	8.90	55[1]	14.5	21	0.16
1985	42.6	44.4	8.80	47.0	34.5	NA	0.13
1986	43.5	45.6	8.75	50.7	NA	NA	0.11
Avg.	42.3	44.0	8.82	50.9	24.5	21	0.13
Comb. Avg.	42.3	44.0	8.82	53.9	24.5	21	0.14

[1] Converted from older embeddedness ranking scale.

Actual embeddedness on Trapper Creek ranged from only 10 to 47% greater than predicted values using the cumulative approach, and averaged only 20% greater (both sites combined) during the test years. In addition, embeddedness predictions increased between 1985 and 1986 by 2%, very close to the percentage increase (both sites averaged) that was actually observed during that period (this trend was not supported by embeddedness measurements in 1984, but the slightly greater imprecision in that year's measurement may have obscured it).

The only core data for estimating depth fines was from 1984, which, as we have already suggested, may be unreliable. At any rate, the percentage of depth fines predicted by FISHSED-1 using the cumulative approach was 100% greater than the actual measurement.

FISHSED-1 predictions of summer rearing capacity again bore no resemblance to actual densities of fish. The predictions were closer to reality because the predicted embeddedness was higher, but the response curves, particularly the curve for age 0+ cutthroat trout, predict such high densities that the small decline in predicted capacity is essentially irrelevant. Actual densities of cutthroat trout were still nearly *two orders* of magnitude lower than densities predicted by FISHSED-1.

Although the cumulative analysis nearly doubled the predicted values for embeddedness and subsurface fines, it only predicted a reduction in fish density from 9.6 to 8.8 fish/m^2, or 0.08%. This is a serious limitation of FISHSED-1 because, even though this drop in predicted density is trivial, the reduced density is predicted to be 4 to 5 times actual densities.

South Fork Red River

The cumulative approach with FISHSED-1 was inferior to the non-cumulative approach on the SFRR sites, and consistently overestimated actual physical habitat and salmonid density conditions (Table 11).

Table 11.--Comparison of actual fish population densities and habitat conditions with FISHSED-1 model predictions (cumulative approach), South Fork Red River, Nez Perce National Forest, Idaho. All values except fish densities and carrying capacities are expressed as a percentage; carrying capacities are expressed as fish/m2.

	Predicted Values				Actual Values						
			Summer Rearing Cap.		Embeddedness			Summer Fish Density			
Year	Embedded	Fines	Steel.	Chin.	Ocular	Hoop	Fines	Steel.	Cutt.	Chin.	Total
			-- Upper South Fork Red River --								
1984	64.7	74.7	7.17		48 [1]	21.4	NA	0.00	0.02	0.13	0.15
1985	65.9	75.4	7.07		41.2	33.2	36.7	0.01	0.04	0.00	0.05
1986	66.8	76.7	6.98		34.7	NA	NA	0.01	0.04	0.00	0.05
Avg.	65.8	75.6	7.07		41.3	27.3	36.7	0.01	0.03	0.04	0.08
			-- Lower South Fork Red River --								
1984	64.7	74.7	7.17		63 [1]	21.4	NA	0.00	0.03	0.04	0.07
1985	65.9	75.4	7.07		42.9	33.2	36.7	0.01	0.06	0.01	0.08
1986	66.8	76.7	6.98		37.2	NA	NA	0.00 [2]	0.04	0.00	0.04
Avg.	65.8	75.6	7.07		47.7	27.3	36.7	0.00	0.04	0.02	0.06
Comb. Avg.	65.8	75.6	7.07		44.5	27.3	36.7	0.01	0.04	0.03	0.07

[1] Converted from older embeddedness ranking scale.

[2] One fish collected.

FISHSED-1 predicted embeddedness levels that ranged from 3 to 92% greater than actual ocular embeddedness, and 98 and 202% greater than hoop embeddedness for 1984 and 1985, respectively. On average, cumulative FISHSED-1 overpredicted embeddedness in the SFRR sites by 65%.

Whereas the non-cumulative approach resulted in an underprediction of depth fines by about 50%, the cumulative approach overpredicted fine sediments by about 100%.

North Fork Red River

For this study area, the cumulative technique was identical to the non-cumulative technique (Table 3). The last sediment yield entry was in 1971, presumably allowing ample time for stream recovery prior to the test years of 1984, 85, and 86.

Red River

As in the case of the SFRR sites, cumulative FISHSED-1 predictions consistently overestimated actual physical and salmonid density conditions on the RR sites (Table 12).

Table 12.--Comparison of observed fish habitat conditions with FISHSED-1 model predictions, Red River (below Red River R.S.), Nez Perce National Forest, Idaho. All values except carrying capacities are expressed as a percentage; carrying capacities are expressed as fish/m2.

	Predicted Values		Observed Values		
			Embeddedness		
Year	Embedded	Fines	Ocular	Hoop	Fines
		-- Upper Red River --			
1984	100.0 [1]	83.3	58 [2]	NA	30.7
1985	100.0	84.6	49.0	54.8	35.8
1986	100.0	85.9	64.1	NA	NA
Avg.	100.0	84.6	57.0	54.8	33.3
		-- Lower Red River --			
1984	100.0	83.3	65	NA	30.7
1985	100.0	84.6	51.1	54.8	35.8
1986	100.0	84.6	60.8	NA	NA
Avg.	100.0	84.6	59.0	54.8	33.3
Comb. Avg.	100.0	84.6	58.0	54.8	33.3

[1] Embeddedness predictions held at 100%.

[2] Converted from older embeddedness ranking scale.

Cumulative FISHSED-1 embeddedness predictions reached 100%, which was 104% greater than smallest actual ocular embeddedness measured, and 72% greater than the combined average. The hoop embeddedness (which included samples from pool habitats not conforming to Burns and Edwards [1984, 1985] criteria) was similar to the combined average ocular embeddedness, and was also well below the cumulative prediction.

Abundance of depth fines was also overestimated by FISHSED-1 using the cumulative approach. FISHSED-1 predictions were 171 and 136% greater than actual depth fines abundances for 1984 and 1985, respectively, for an average overprediction of 154%.

PHYSICAL HABITAT RELATIONSHIPS

Surface and Depth Fines

An apparently real but statistically insignificant positive relationship was found between surface and depth fines for the Red River drainage sites (Figure 8). In this relationship, surface fine abundance was about 75% of depth fine abundance. These data were based on all Red River drainage depth fines data, however, and the accuracy of some has previously been questioned. Incorporation of SFSR data should help clarify the relationship.

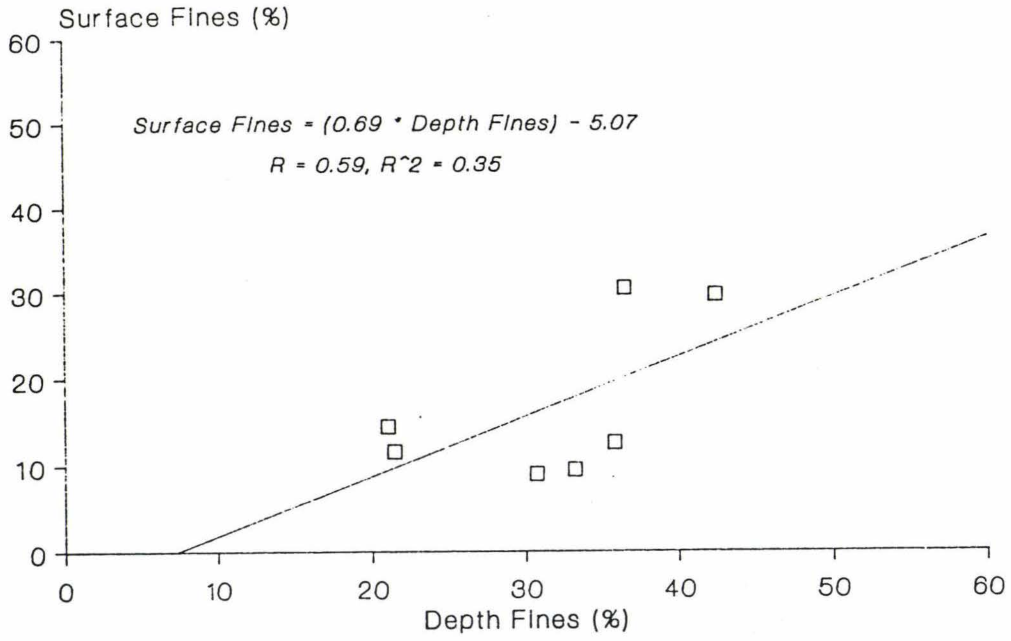

Figure 8.--Relationship between surface and depth fines, North Fork Red River, 1984-1985.

Embeddeness and Surface Fines

These data are not yet available

Depth Fines and Embryo Survival

Egg to alevin survival studies in 1986-87 represented minimum survival values because of the potential for loss of emerging larvae through the unclosed tops of the egg baskets and possible incursion of predators. This precludes use of 1987 results for developing anything more than the relationship between depth fines and the minimum survival that can be expected. This situated was largely rectified in the 1987-88 plantings in the Poverty Flat study sites, though some cases of ruptures in the tops of the baskets occurred. In many cases, complete failure of the artificial egg pocket to produce viable young could be traced to these causes and excluded from analysis.

Figure 9.--Relationships between embeddedness and percent surface fine sediment, SFSR and RR drainages (to be added).

FISHSED-1 generally predicted higher survival than was actually observed (Appendix 14), Figures 10 and 11), even when there was no larval escapement through open basket tops. There were a few instances of actual survival being higher than predicted, particularly in the 1987-88 plantings, and two of the observed survival figures for the NFRR site were much higher than predicted; survival in these cases exceeded predictions by 39 and 51%, respectively.

In some ways, the actual point scatters from the the field data analysis (Figures 10 and 11) were similar to the data scatter in FISHSED-1´s chinook survival response curve (Figure 2). Specifically, there was potentially high but quite variable survival in the 15 to 30% depth fines range. Considerably more instances of very low embryo survival occurred in the field study than are shown on FISHSED-1's survival curve. This was possibly due to inherent differences between field and laboratory conditions, or weaknesses in the design of the field tests (e.g. potential for alevin escape and predation). For the Poverty Flat data, there is no evidence than any embryo survival can be expected when depth fines in the egg pocket exceed about 27%.

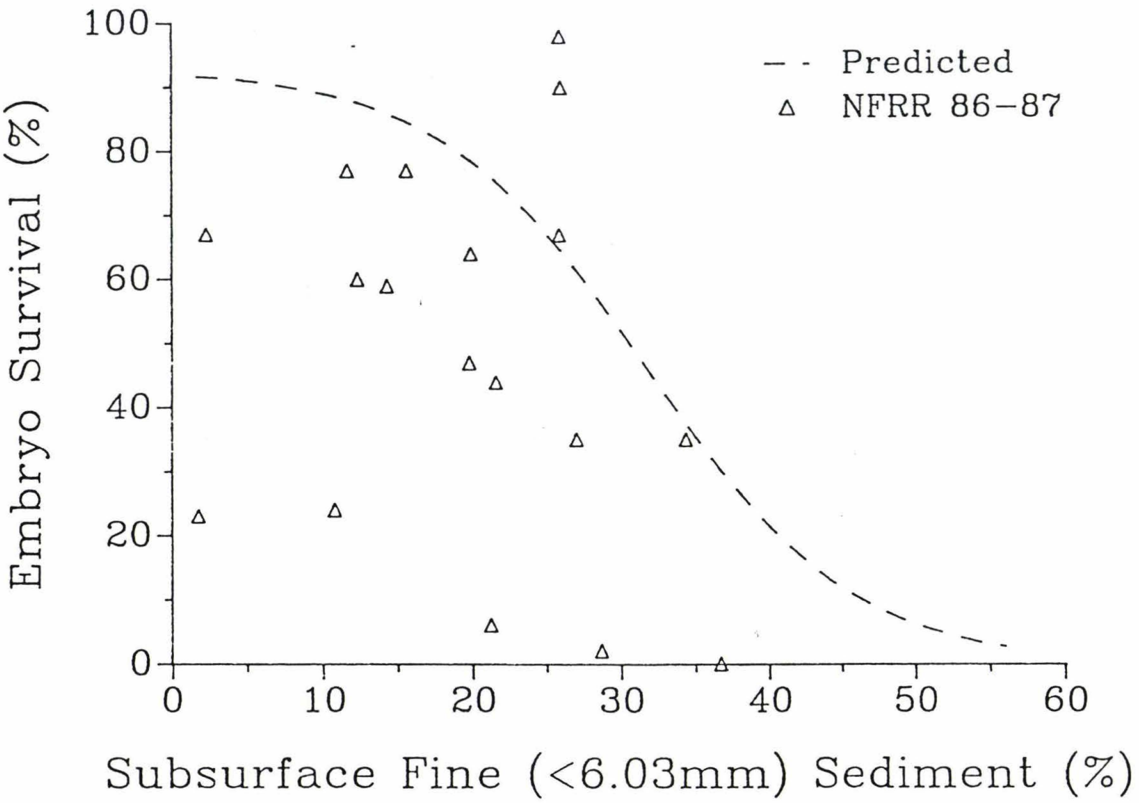

Figure 10.--Relationship between percent depth fines and minimum chinook salmon embryo survival, North Fork Red River, 1986-1987.

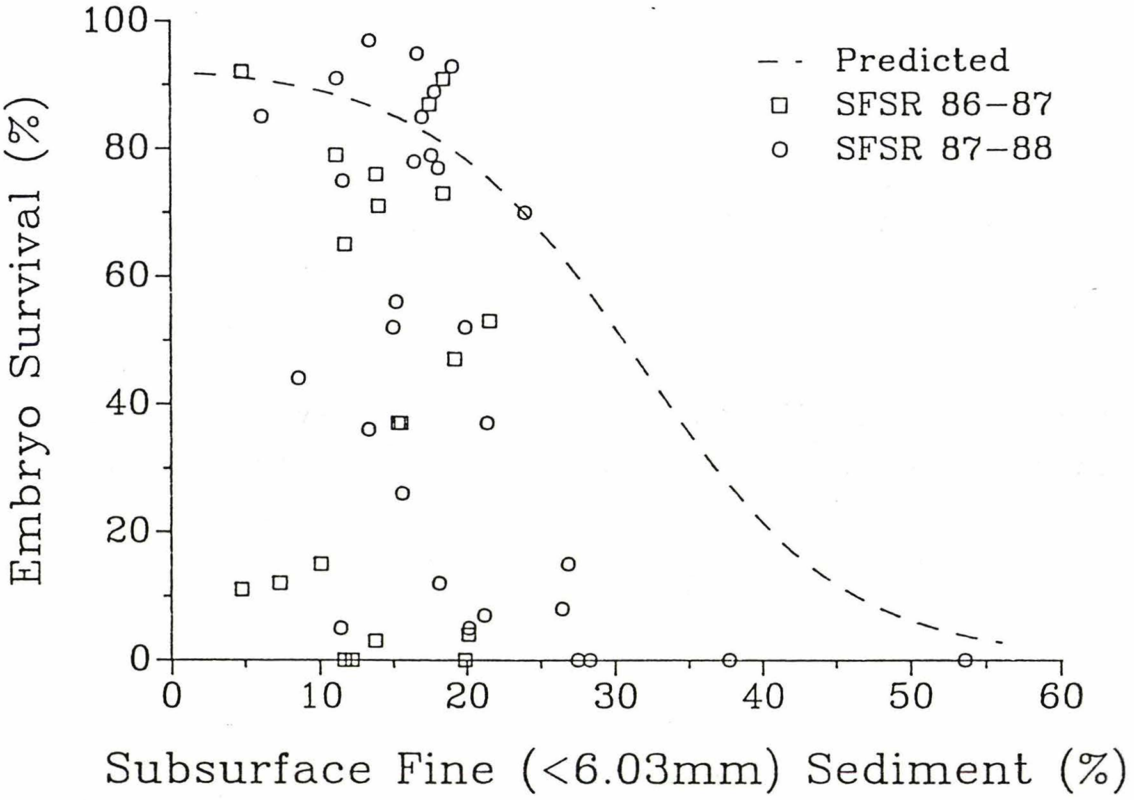

Figure 11.--Relationship between percent depth fines and chinook salmon embryo survival, Poverty Flat, South Fork Salmon River, 1986-1988.

It is interesting to note that embryo survival in the NFRR site was apparently higher at higher levels of depth fines than in the Poverty Flat site. These salmon may be better adapted to relatively greater levels of fines, or other environmental factors may have moderated the effects of the greater amounts of depth fines. Red River in the areas sampled is, in fact, a "dirtier" system than the SFSR areas sampled.

Embeddedness and Summer Rearing Capacity

Summer rearing densities predicted by FISHSED-1 were clearly many times higher than actual densities for trout, while actual chinook fry densities were higher than predicted. Plotting of our actual trout fry densities against actual (ocular) embeddedness produced a positive relationship (Figure 12), while chinook salmon fry densities exhibited the expected negeative relationships (Figure 13).

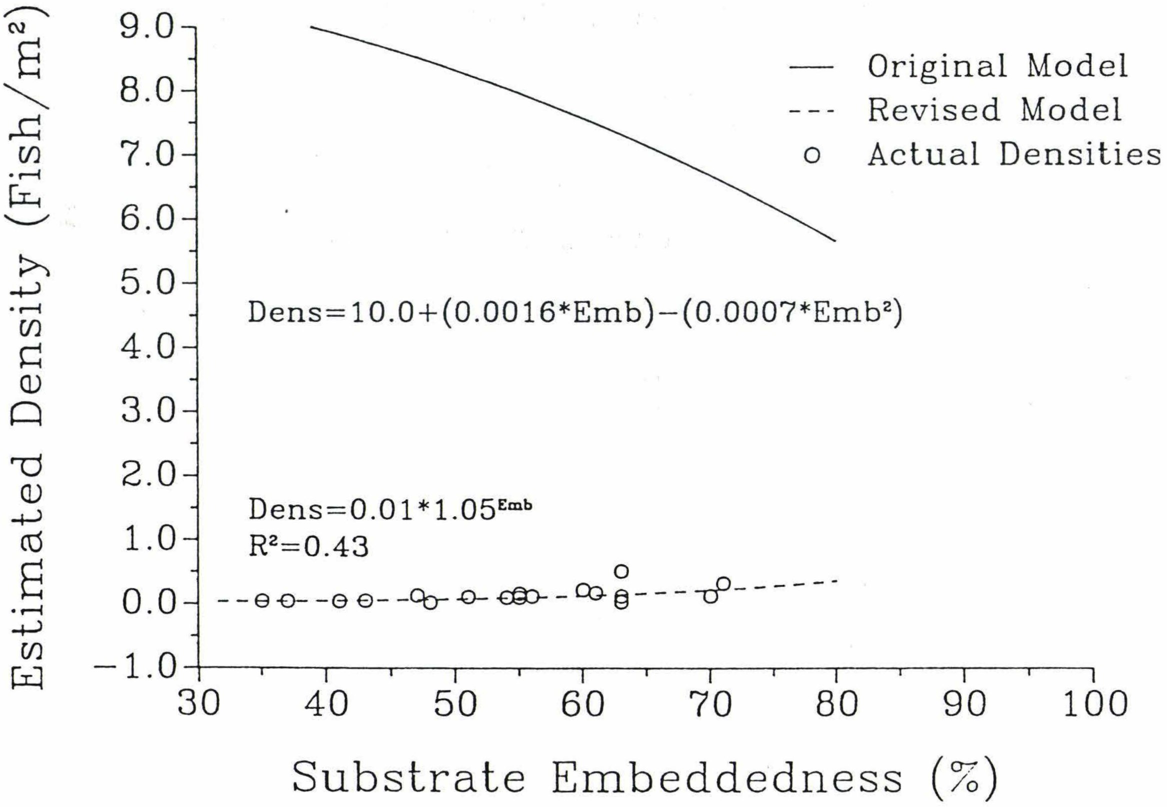

Figure 12.--Relationship between embeddedness and summer trout fry density, SFSR and RR drainages, 1984-1986.

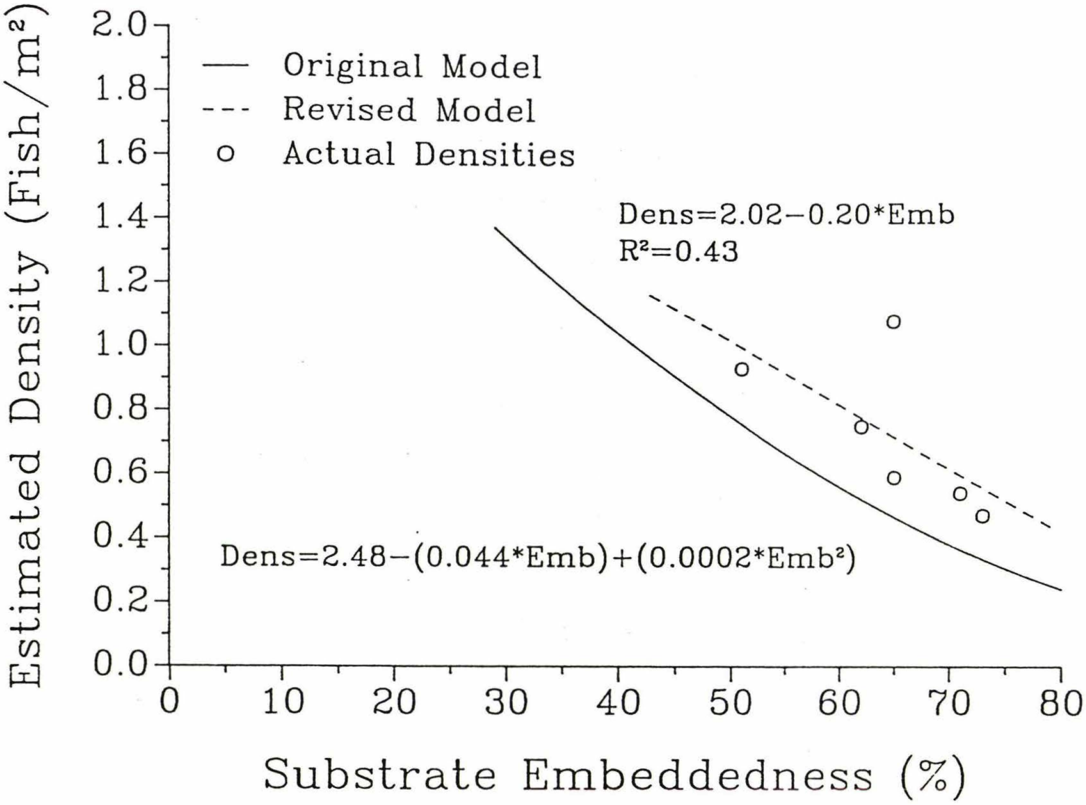

Figure 13.--Relationship between embeddedness and summer chinook fry density, North Fork Red River, 1984-1986.

FISHSED-2

Delayed Approach

Declining Approach

Physical Habitat Relationships

The high variability in salmon egg to alevin survival makes the use of gross predictions of average survival based on the relationships of Figure 14 more realistic. The relationship depicted in Figure 14 was developed for the SFSR, and may be shifted somewhat toward higher survival at higher depth fines levels for the Clearwater drainage. Only minimum survival data are available for NFRR, but it suggests expanding the "Good Zone" to about 30% depth fines. The "Marginal Zone" could reasonably be expanded the same 10% , which would make the "Dead Zone" begin at 37% depth fines. Since some users of FISHSED-2 may continue to desire exact percentage survival predictions, alternate curvilinear relationships are presented in Appendix 5. The most relaistic of these functions (Figure 15 for fines <6.03mm and Figure 16 for fines <.8mm) are presented as an option in the computer programs; in addition, the other functions can be modeled as part of FISHSED-2's customizing facility for those workers who feel that a certain relationship may fit their situation more closely.

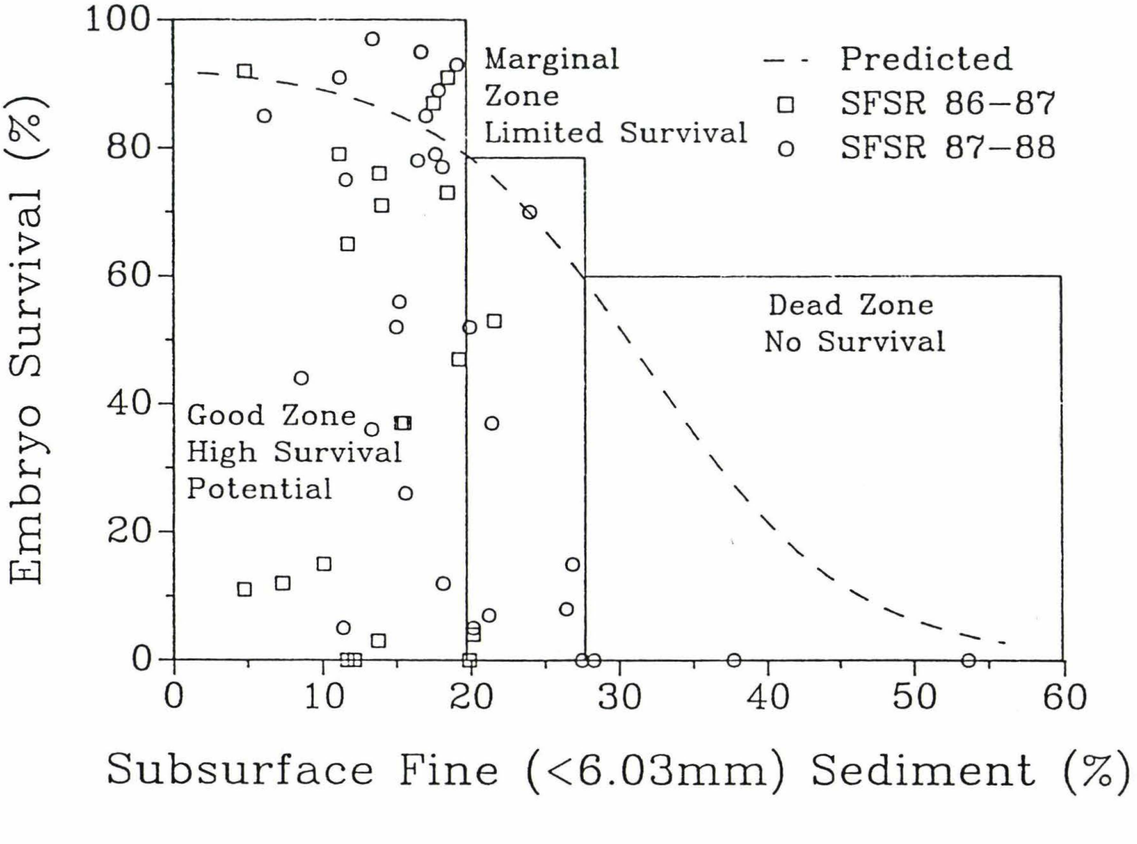

Figure 14.--Proposed predictive relationship between depth fines and chinook embryo survival using "survival zones" and expected average survival rates.

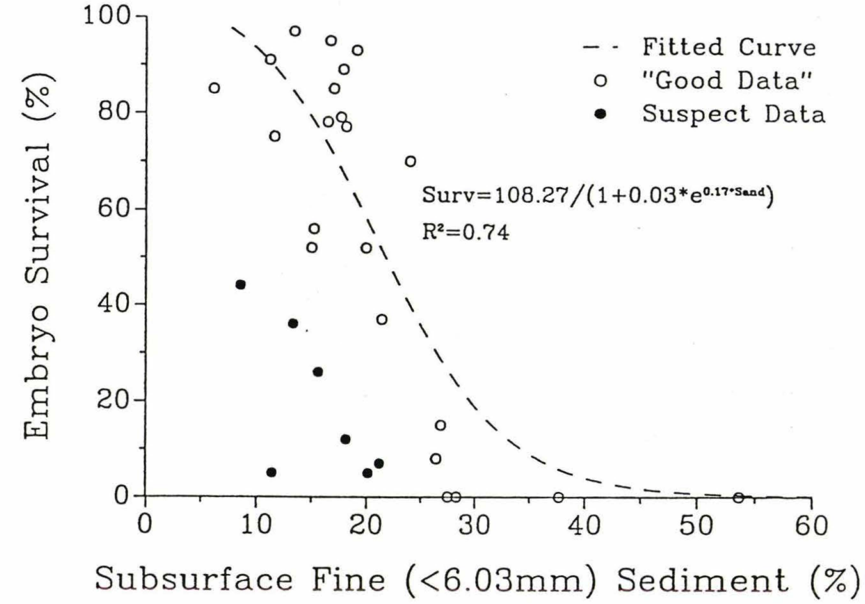

Figure 15.--Proposed functional relationship between chinook embryo survival and percent depth fines (<6.03 mm) in the egg pocket.

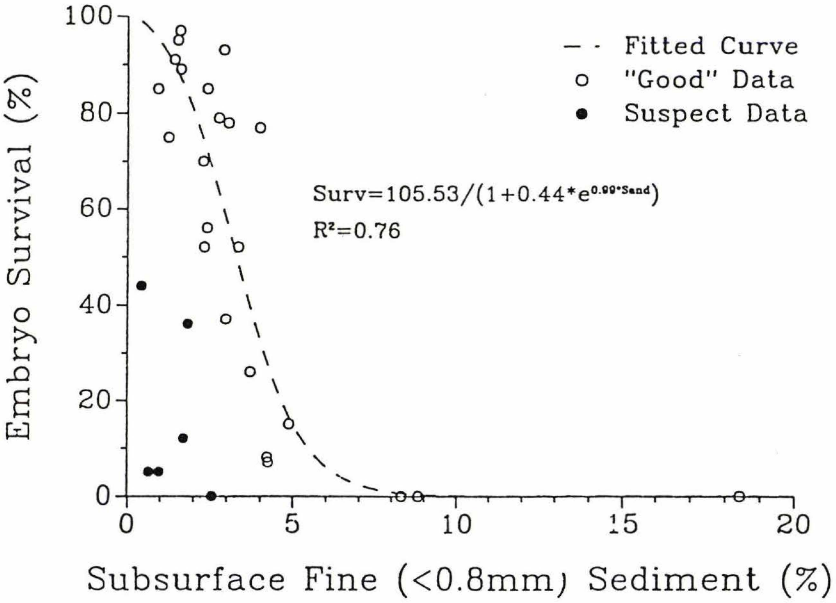

Figure 16.--Proposed functional relationship between chinook embryo survival and percent depth fines (<0.8 mm) in the egg pocket.

Results for fry densities as a function of embeddedness suggest not only a complete revision of the relationships used by FISHSED-1 to predict rearing capacity based on embeddedness, but also a philosophical overhaul of the common belief among many fisheries biologists that embeddedness is necessarily an important limiting factor; chances are that it is not. While chinook fry densities did decline with increasing embeddness, their densities were higher than predicted by FISHSED-1. FISHSED-2 incorporates the linear functional relationship shown in Figure 17; trout fry densities, regardless of species, actually increased somewhat with embeddeness, and FISHSED-2 thus incorporates the curvilinear relationship also shown in Figure 17.

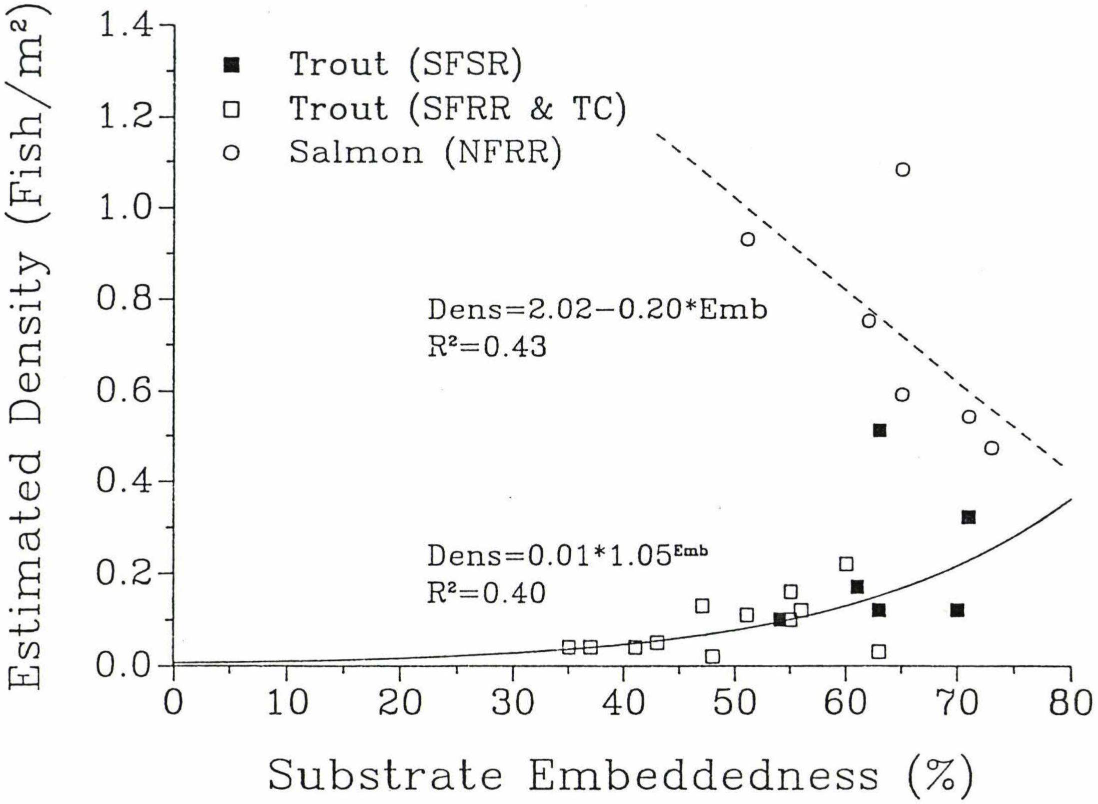

Figure 17.--Linear and curvilinear relationships used to model chinook and trout fry densities, respectively, in FISHSED-2.

DISCUSSION

Weaknesses in FISHSED-1 belong to two categories: structural weaknesses related to the validity of the laboratory studies used to develop the model and to the ability of the coefficients selected in generating accurate predictions; and philosophical difficulties related to model design. Both of these categories of problems present users with difficulties in relating model inputs (e.g. R1-R4 model outputs) and outputs (e.g. FISHSED-1 predictions) to the real-world situations they face. It must be noted that some of the difficulty with respect to the philosophical failings of FISHSED-1 are undoubtedly created by inadequacy in the R1-R4 model. Specifically, the R1-R4 model leaves the user of FISHSED-1 with no indication of the expected validity of its outputs and without any clue as to how to incorporate the related factors of sediment disposition within the critical reach and overall watershed recovery processes. The fact that FISHSED-1 fails to allow for watershed recovery or in-reach sediment storage is probably due to the same failure in the R1-R4 model.

Since the philosophical difficulties are fundamental, we will discuss with them first. The principal problems, as we see them, are, first, the complete independence of model components, and, second, the assumption of single limiting factors in each component being sufficient to predict the fish population statistics of interest.

Philosophical Difficulties

The fundamental philosophical weakness with the FISHSED-1 modeling process is an overly simplified view of the world. This weakness is expressed in several ways, but particulary in the way changes in the watershed from year to year are poorly incorporated, and in the way potential ecological interactions are largely disregarded. Such philosophy may be expedient, but it represents bad ecology.

Ecosystem functioning is largely ignored in the straightforward application of FISHSED-1. The significance of this fact is that the user of is generally expected to input one data point representing sediment delivery over "natural" levels (which may themselves be unknown) to derive predictions of changed habitat conditions and how this altered state will impact local fish populations. In this process, only influences from actual or potential changes in delopment activity are used to generate a prediction of increased sediment delivery; the influence of climate is largely ignored, the cyclic nature of anadromous fish populatuions is ignored, random fluctuations in resident fish populations are ignored, the influences of competition are ignored, the influence of the specific local riverine-riparian habitat, and the status of other important ecosystem variables that may influence populations are ignored.

The clearest example of the lack of an "ecological perspective" is the search for a single limiting factor controlling fish populations instead of incorporating the effects of ecological interactions in modeling fisheries responses to management activities is reflected in our embryo survival results. Embryo survival in the SFSR was highly variable over the range of zero to about 20% depth fines, and ranged from zero to 100% survival. We have termed this region the "Good Zone" because average survival was quite high, but the high variability suggested that other environmental factors were generally more important determinants of survival than depth fines. From about 20 to 27% depth fines, survival remained variable but appeared to generally be declining. We have termed this region of the curve the "Marginal Zone" because survival was only moderate, suggesting that depth fines were becoming increasingly important as determinants of survival. We have termed the region above 27%

depth fines the "Dead Zone" because it appears that depth fines become an absolutely limiting factor in this range, and little, if any, survival can be expected. Consequently, functional relationships used to model survival in FISHSED-2 ignore this region, attempting to predict survival only in the region where there is some real liklihood of survival.

Similarly, FISHSED-1 attempted to predict the carrying capacities of salmonids, as reflected by actual densities, without regard to the nature of the local fish community. Thus, FISHSED-1 would predict the same density of steelhead trout in a stream reach regardless of the presence or absence of potential salmonid competitors of other species.

Structural Difficulties

COMPUTER APPLICATIONS

Refinements to FISHSED-1 have been discussed in this report, and two user-interactive programs that allow use of these refinements (FISHSED-2) have been developed.

The first of these programs, FS-1, was written in IBM BASICA and compiled with Microsoft QuikBASIC Compiler, version 3.0. It is intended for use on personal computers using MS or PC DOS, version 2.0 or higher. Some language elements of the BASICA version may not be suitable for use with the BASIC interpreter on the DG system. Source code is listed in Appendix 2.

The second program, FS-2, was written in FORTRAN and compiled with Microsoft FORTRAN Compiler, version 3.31 and offers the same model enhancements as FS1. It was also designed for use on personal computers using MS or PC DOS, version 2.0 or higher. This program, unlike FS-1, can be readily converted to use on the U.S. Forest Service´s Data General system. Source code is listed in Appendix 3.

Programs are available from the authors, including text and executable versions with instructions for use, upon receipt of a blank, formatted diskette (5.25 in DS/DD or 3.5 in micro-diskette).

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APPENDIX 1: GLOSSARY

Anadromous - Fish that migrate from the ocean to spawn and rear their young in freshwater, the young then migrating as smolts to the ocean to mature. Anadromous fish include Pacific salmon (*Oncorhynchus spp.*), some trout (e.g. steelhead, *Salmo gairdneri*) and char (e.g. *Dolly Varden, Salvelinus malma), and American shad (Alosa sapidissima*).

Alevin - A fish that has just hatched and still retains the yolk mass.

Baseline sediment yield - A more or less constant sediment yield level that is in approximate balance with overall watershed erosivity.

Bedload -

Channel roughness -

Channel type - A stream channel designation based on hierarchical classifications (e.g. Collotzi 1974; Espinoza et al. 1981; Rosgen and Silvey 1985). Type designations are alphanumeric and based on such physical characteristics as channel width, depth, velocity, discharge, bed roughness, bed material particle size, and sinuosity. The various channel types are assumed to transport and/or accumulate sediments in different ways.

Cobble - Moderately large substrate particles ranging from 3.0 to 11.9 in (76.1 to 304.0 mm [Platts et al. 1983]). This substrate class forms the centrum of anadromous salmonid egg pockets, provides winter hiding cover for anadromous salmonid fry, and serves as habitat for aquatic macroinvertebrates.

Critical stream reach - The portion of stream that will exhibit changes in fish habitat condition from anticipated sediment yields from alternative land use activities. They may be used to represent the type of stream habitat of interest to land-use planners.

Depth fines - Fine sediments that are located from the streambed surface to 8 in (20.3 cm) below the streambed surface. These sediments occur within the vertical horizon of the streambed that is critical for anadromous fish spawning.

Developed baseline sediment yield - A more or less constant sediment yield level that is in approximate balance with overall watershed erosivity at existing levels of watershed development.

Egg pocket - The portion of a redd in which the eggs have been deposited by the spawning female. Chinook salmon produce 5 or 6 egg pockets that lie at a depth of about 7 to 17 in (18 to 43 cm) (Chapman and McLeod 1987).

Embeddedness - A rating indicating the degree to which larger substrate particles are impacted by fine sediments.

Escapement -

Fine sediments - Substrate particles that are less than 0.25 in (6.4 mm) in diameter. Other researchers (e.g. Platts et al. 1983) have used other size categories to define fine sediments, but 0.25 in (6.4 mm) was chosen for the FISHSED-1 model.

Fish biomass - The weight of fish per unit (usually surface area) of stream.

Fish density - The number of fish per unit (usually surface area) of stream.

Fish habitat recovery - Tendency of aquatic habitat to return to pre-disturbance conditions. Work on the South Fork of the Salmon River is the best available documentation of recovery of riverine substrate conditions to "near-normal" following an extended period of excessive sediment input.

Fry - Juvenile fish tending to occur in clusters or schools.

Glide - Stream habitat category that is intermediate between riffle and pool with respect to depth and velocity. This type of habitat is generally chosen for spawning by anadromous salmonids.

Gravel - Substrate particles that range in size from 0.25 to 2.9 in (6.4 to 76.0 mm).

Natural sediment yield - Sediment yield that would have occurred under pristine conditions, prior to any watershed development.

Percent fines -

Pool -

Pool volume -

Pseudo-baseline sediment yield - Same as "developed baseline sediment yield."

Rearing -

Rearing area - The area of a stream in which juvenile fish reside after they emerge from the redd. These areas typically comprise glide and pool habitats.

Redd - The disturbed area in the streambed substrate in which fish lay their eggs. In salmonids, the redd is dug by the spawning female.

Resident - Non-migratory (i.e. non-anadromous) individuals or populations.

Riffle -

Rubble - Same as "cobble."

Run - Same as "glide."

Sediment disposition -

Sediment routing -

Sediment storage -

Sediment transport -

Sediment yield - Quantity of sediment produced by the watershed upstream of a given stream section. Sediment yield may be expressed as tons/mi^2/year (absolute yield) or as a percentage over natural sediment yield (relative yield).

Smolt - That stage of an anadromous fish's life cycle when they are undergoing morphological changes just prior to or during their migration seaward from their rearing areas.

Spawning -

Spawning area -

Subsurface fines - Same as "depth fines."

Surface fines -

Watershed recovery - Tendency of the watershed itself to return to "near normal" conditions following development. Watershed recovery involves redevelopment of vegetation that reduces erosivity, and proceeds more quickly than aquatic habitat recovery.

Winter habitat - Stream habitat occupied by fish during winter months. Winter habitat may comprise deep pools, rubble-boulder glides and riffles, or warmer water areas. The FISHSED-1 model has keyed on the rubble-boulder glides and riffles.

APPENDIX 2: FS-1 PROGRAM SOURCE CODE (BASIC)

APPENDIX 3: FS-2 PROGRAM SOURCE CODE (FORTRAN)

```
C     Program:      FS-2.FOR (Executable = FS-2.EXE)
C
C     Purpose:      Predict changes in fish habitat quality and fish population
C                   responses to predicted habitat changes resulting from predicted
C                   increases in sediment yield.
C
C     Language:     FORTRAN77
C                   Compiled with Microsoft FORTRAN Compiler, Version 3.31.
C                   For use with IBM or capatibles using PC or MS DOS, Version 2.0
C                   or later.
C
C     Written by:   Rodger L. Nelson
C                   Biological Technician (Fisheries)
C                   USDA - Forest Service
C                   Intermountain Research Station
C                   Forestry Sciences Laboratory
C                   Boise, Idaho
C
C     ---------------------------------------------------------------------
C
  100 DIMENSION EMBED(10),FINES(10),YIELD(10),SURV(10),SUMK(10),WINK(10)
      CHARACTER*1  MODEL,CHANTYPE,FISHTYPE,INSTR
      CHARACTER*25 OUTFILE,CRITRCH
C
C     ---------------------------------------------------------------------
C
C     Model Selection
C
      KOUNT=1
  200 DO 201 K=1,3
        WRITE (*,900)
  201 CONTINUE
      INCR2=0
      WRITE (*,800)
      WRITE (*,900)
      WRITE (*,801)
      WRITE (*,802)
      WRITE (*,803)
      WRITE (*,804)
      WRITE (*,805)
      WRITE (*,806)
      WRITE (*,807)
      WRITE (*,900)
      WRITE (*,808)
      DO 203 K=1,4
        WRITE (*,900)
  203 CONTINUE
      WRITE (*,902)
```

```
 204  WRITE (*,900)
      WRITE (*,903)
      WRITE (*,900)
      WRITE (*,904)
      WRITE (*,905)
      WRITE (*,900)
      WRITE (*,906)
      READ  (*,´(A1)´)MODEL
C     -----
      IF     (MODEL.EQ.´A´) THEN
        GOTO 300
      ELSEIF (MODEL.EQ.´a´) THEN
        GOTO 300
      ELSEIF (MODEL.EQ.´B´) THEN
        GOTO 300
      ELSEIF (MODEL.EQ.´b´) THEN
        GOTO 300
      ELSE
        GOTO 205
      ENDIF
C     -----
 205  WRITE (*,900)
      WRITE (*,908)
      GOTO 204
C
C     ------------------------------------------------------------------
C
C     Data Entry Section
C
 300  WRITE (*,900)
      WRITE (*,901)
      WRITE (*,900)
 301  WRITE (*,910)
      WRITE (*,915)
      READ  (*,*)INPUTS
      WRITE (*,900)
      IF (INPUTS.GE.10) THEN
        WRITE (*,900)
        WRITE (*,908)
        WRITE (*,900)
        GOTO 301
      ELSE
        GOTO 302
      ENDIF
 302  WRITE (*,911)
      READ  (*,*)EMBED1
      WRITE (*,912)
      READ  (*,*)FINES1
 303  WRITE (*,913)
      READ  (*,´(A1)´)CHANTYPE
C     ----------
      IF     (CHANTYPE.EQ.´A´) THEN
```

```
        GOTO 304
      ELSEIF (CHANTYPE.EQ.´B´) THEN
        GOTO 304
      ELSEIF (CHANTYPE.EQ.´C´) THEN
        GOTO 304
      ELSEIF (CHANTYPE.EQ.´a´) THEN
        CHANTYPE=´A´
        GOTO 304
      ELSEIF (CHANTYPE.EQ.´b´) THEN
        CHANTYPE=´B´
        GOTO 304
      ELSEIF (CHANTYPE.EQ.´c´) THEN
        CHANTYPE=´C´
        GOTO 304
      ELSE
        WRITE (*,900)
        WRITE (*,908)
        WRITE (*,900)
        GOTO 303
      ENDIF
C     ----------
 304  WRITE (*,914)
      READ  (*,´(A1)´)FISHTYPE
C     ----------
      IF      (FISHTYPE.EQ.´C´) THEN
        GOTO 305
      ELSEIF (FISHTYPE.EQ.´S´) THEN
        GOTO 305
      ELSEIF (FISHTYPE.EQ.´c´) THEN
        FISHTYPE=´C´
        GOTO 305
      ELSEIF (FISHTYPE.EQ.´c´) THEN
        FISHTYPE=´B´
        GOTO 305
      ELSE
      WRITE (*,900)
      WRITE (*,908)
      WRITE (*,900)
      GOTO 304
      ENDIF
 305  WRITE (*,900)
      YIELD1=0
      DO 306,K=1,INPUTS
        INCR1=5+K
        WRITE (*,916)INCR1,K
        READ  (*,*)YIELD(K)
 306  CONTINUE
C     ----------
      IF (MODEL.EQ.1) GOTO 400
      IF (MODEL.EQ.2) GOTO 500
C
C     ---------------------------------------------------------------------------
```

```
C
C     "ORIGINAL" Option
C
 400  WRITE (*,900)
C     ----------
C     Predict Embeddedness
C
      DO 401,K=1,INPUTS
      IF    (K.EQ.1) THEN
        CUREMBED=EMBED1
      ELSE
        CUREMBED=EMBED(K-1)
      ENDIF
      IF     (CHANTYPE.EQ.'A') THEN
        EMBED(K)=CUREMBED+(0.09*YIELD(K))
      ELSEIF (CHANTYPE.EQ.'B') THEN
        EMBED(K)=CUREMBED+(0.09*YIELD(K))
      ELSEIF (CHANTYPE.EQ.'C') THEN
        EMBED(K)=CUREMBED+(0.16*YIELD(K))
      ENDIF
 401  CONTINUE
C     ----------
C     Predict Depth Fines
C
 410  DO 411 K=1,INPUTS
      IF    (K.EQ.1) THEN
        CURFINES=FINES1
      ELSE
        CURFINES=FINES(K-1)
      ENDIF
C     ----------
      FINES(K)=CURFINES+(0.12*YIELD(K))
 411  CONTINUE
C     ----------
C     Predict Embryo Survival Potential
C
 420  IF     (FISHTYPE.EQ.'C') THEN
        SURV1=92.95/(1+EXP(-4.559+0.1442*FINES1))
      ELSEIF (FISHTYPE.EQ.'S') THEN
        SURV1=80.73/(1+EXP(-9.425+0.3677*FINES1))
      ENDIF
      DO 421 K=1,INPUTS
      IF     (FISHTYPE.EQ.'C') THEN
        SURV(K)=92.95/(1+EXP(-4.559+0.1442*FINES(K)))
      ELSEIF (FISHTYPE.EQ.'S') THEN
        SURV(K)=80.73/(1+EXP(-9.425+0.3677*FINES(K)))
      ENDIF
 421  CONTINUE
C     ----------
C     Predict Summer Rearing Capacity (Ks)
C
 430  IF     (FISHTYPE.EQ.'S') THEN
```

```
        SUMK1=100+(0.016*EMBED1)-(0.007*EMBED1**2)
        DO 431 K=1,INPUTS
          SUMK(K)=100+(0.016*EMBED(K))-(0.007*EMBED(K)**2)
 431    CONTINUE
      ELSEIF (FISHTYPE.EQ.´C´) THEN
        SUMK1=100-(1.79*EMBED1)+(0.0081*EMBED1**2)
        DO 432 K=1,INPUTS
          SUMK1=100-(1.79*EMBED(K))+(0.0081*EMBED(K)**2)
 432    CONTINUE
      ENDIF
C     ----------
C     Predict Winter Carrying Capacity (Kw)
C
 440  IF     (FISHTYPE.EQ.´S´) THEN
        WINK1=100*EXP(-0.026*EMBED1)
        DO 441 K=1,INPUTS
          WINK(K)=100*EXP(-0.026*EMBED(K))
 441    CONTINUE
      ELSEIF (FISHTYPE.EQ.´C´) THEN
        WINK1=100*EXP(-0.034*EMBED1)
        DO 442 K=1,INPUTS
          WINK(K)=100*EXP(-0.034*EMBED(K))
 442    CONTINUE
      ENDIF
C     ----------
      GOTO 600
C     ----------------------------------------------------------------------------
C
C     "ENHANCED" Option
C
C
 500  WRITE (*,900)
      DO 501,K=1,INPUTS
        IF     (CHANTYPE.EQ.´A´) THEN
          EMBED(K)=EMBED1+0.9*(YIELD(K))
        ELSEIF (CHANTYPE.EQ.´B´) THEN
          EMBED(K)=EMBED1+0.9*(YIELD(K))
        ELSEIF (CHANTYPE.EQ.´C´) THEN
          EMBED(K)=EMBED1+0.16*(YIELD(K))
        ENDIF
 501  CONTINUE
C     ----------
      WRITE (*,900)
      WRITE (*,919)EMBED1
      DO 502,K=1,INPUTS
        WRITE (*,920)K,EMBED(K)
 502  CONTINUE
 503  GOTO 1000
C
C     ----------------------------------------------------------------------------
C
C     Screen Output Section
```

```
C
 600  WRITE (*,901)
      WRITE (*,900)
      WRITE (*,917)
      WRITE (*,900)
      WRITE (*,918)
      WRITE (*,900)
      WRITE (*,919)EMBED1,FINES1
      DO 601,K=1,INPUTS
        WRITE (*,920)K,EMBED(K),FINES(K)
 601  CONTINUE
C     ----------
 610  WRITE (*,901)
      WRITE (*,921)SURV1,SUMK1
      DO 611,K=1,INPUTS
        WRITE (*,922)K,SURV(K),SUMK(K)
 611  CONTINUE
C     ----------
 620  WRITE (*,901)
      IF (INPUTS.LT.4) GOTO 621
      WRITE (*,900)
      PAUSE
      WRITE (*,900)
 621  WRITE (*,923)WINK1,YIELD1
      DO 622,K=1,INPUTS
        WRITE (*,924)K,WINK(K),YIELD(K)
 622  CONTINUE
      WRITE (*,901)
      IF (INPUTS.LT.5) GOTO 700
      WRITE (*,900)
      PAUSE
C
C     -------------------------------------------------------------------------
C
C     Filing and Wrap-Up Section
C
 700  INCR2=INCR2+INCR1
 701  WRITE (*,900)
      INCR2=INCR2+1
      WRITE (*,925)INCR2
      WRITE (*,900)
      WRITE (*,926)
      WRITE (*,927)
      WRITE (*,928)
      WRITE (*,929)
      WRITE (*,900)
      WRITE (*,930)
      READ  (*,'(A1)')INSTR
      WRITE (*,900)
C     ----------
      IF     (INSTR.EQ.'a') THEN
        INSTR='A'
      ELSEIF (INSTR.EQ.'b') THEN
        INSTR='B'
      ELSEIF (INSTR.EQ.'c') THEN
        INSTR='C'
      ELSEIF (INSTR.EQ.'d') THEN
        INSTR='D'
      ENDIF
C     ----------
      IF     (INSTR.EQ.'A') THEN
        OUTFILE='LPT1:'
        GOTO 710
      ELSEIF (INSTR.EQ.'B') THEN
        INCR2=INCR2+1
        WRITE (*,931)INCR2
        WRITE (*,932)
        READ  (*,'(A)')CRITRCH
        INCR2=INCR2+1
        WRITE (*,933)INCR2
        WRITE (*,934)
        READ  (*,'(A)')OUTFILE
        GOTO 710
      ELSEIF (INSTR.EQ.'C') THEN
        KOUNT=KOUNT+1
        GOTO 200
      ELSEIF (INSTR.EQ.'D') THEN
        GOTO 1000
      ENDIF
C     ----------
 710  OPEN(1,FILE=OUTFILE,STATUS='NEW')
      WRITE (1,900)
 711  WRITE (1,800)
      WRITE (1,900)
      WRITE (1,801)
      WRITE (1,802)
      WRITE (1,803)
      WRITE (1,804)
      WRITE (1,805)
      WRITE (1,806)
      WRITE (1,807)
      WRITE (1,900)
      WRITE (1,808)
      DO 712 K=1,2
        WRITE (1,900)
 712  CONTINUE
      WRITE (1,901)
      WRITE (1,900)
      WRITE (1,917)
      WRITE (1,900)
      WRITE (1,918)
      WRITE (1,900)
      WRITE (1,935)
      WRITE (1,'(A)')CRITRCH
      WRITE (1,900)
      WRITE (1,919)EMBED1,FINES1
      DO 713,K=1,INPUTS
        WRITE (1,920)K,EMBED(K),FINES(K)
 713  CONTINUE
C     ----------
 714  WRITE (1,901)
      WRITE (1,921)SURV1,SUMK1
      DO 715,K=1,INPUTS
        WRITE (1,922)K,SURV(K),SUMK(K)
 715  CONTINUE
C     ----------
 716  WRITE (1,901)
      WRITE (1,923)WINK1,YIELD1
      DO 717,K=1,INPUTS
       WRITE (1,924)K,WINK(K),YIELD(K)
 717  CONTINUE
      WRITE (1,901)
      CLOSE(1)
C     ----------
 718  GOTO 701
C
C     --------------------------------------------------------------------------
C
C     Introductory Format Section
C
 800  FORMAT (´#########################################################
     1#####################´)
 801  FORMAT (´                     ########     ########            ###
     1##### ´)
 802  FORMAT (´                    ##          ##
     1   ## ´)
 803  FORMAT (´                   ##          ##
     1  ##  ´)
 804  FORMAT (´                  ######       ########    #####    #####
     1###   ´)
 805  FORMAT (´                 ##                  ##            ##
     1      ´)
 806  FORMAT (´                ##                  ##            ##
     1      ´)
 807  FORMAT (´               ##           ########             ########
     1#     ´)
 808  FORMAT (´#########################################################
     1################RLN##´)
C
C     --------------------------------------------------------------------------
C
C     Program Format Section
C
 900  FORMAT (80X)
 901  FORMAT (´---------------------------------------------------------
     1---------------------´)
 902  FORMAT (' FISHERIES - SEDIMENT RESPONSE MODEL ')
 903  FORMAT ('   Available FISHSED-1 Options: ')
 904  FORMAT ('       A.  Original Model')
 905  FORMAT ('       B.  Enhanced Model [* Not Available *]')
 906  FORMAT ('   Select Desired Option           ---> '\)
 907  FORMAT (I2)
 908  FORMAT (' ! Selection Error -- Try Again')
     1tries !')
 910  FORMAT ('   1.  Enter Number of Events ')
 911  FORMAT ('   2.  Enter Starting Embededness  ---> '\)
 912  FORMAT ('   3.  Enter Starting Fines        ---> '\)
 913  FORMAT ('   4.  Enter Channel Type (A,B,C)  ---> '\)
 914  FORMAT ('   5.  Enter Fish Type   (C or S)  ---> '\)
 915  FORMAT ('       [* Up to a Maximum of 10 *] ---> '\)
 916  FORMAT (2X,I2,'.  Enter Yield, Event # ',I2,'      ---> '\)
 917  FORMAT ('                 PREDICTED SALMONID HABITAT AND POPULATION
     1 RESPONSES')
 918  FORMAT ('                              Original FISHSED-1 Model')
 919  FORMAT (' Pre-Event      ¦     Embeddedness     = ',F6.1,'%    ¦
     1  Fines         = ',F6.1,'%')
 920  FORMAT (' Event # ',I2,'     ¦     Embeddedness     = ',F6.1,'%
     1¦     Fines         = ',F6.1,'%')
 921  FORMAT (' Pre-Event      ¦     Embryo Survival  = ',F6.1,'%    ¦
     1  Summer K      = ',F6.1,'%')
 922  FORMAT (' Event # ',I2,'     ¦     Embryo Survival  = ',F6.1,'%
     1¦     Summer K      = ',F6.1,'%')
 923  FORMAT (' Pre-Event      ¦     Winter K         = ',F6.1,'%    ¦
     1  Yield > Base = ',F6.1,'%')
 924  FORMAT (' Event # ',I2,'     ¦     Winter K         = ',F6.1,'%
     1¦     Yield > Base = ',F6.1,'%')
 925  FORMAT (2X,I2,'.  Available Wrap-Up and Output Options: ')
 926  FORMAT ('           A.  Print Results to Printer')
 927  FORMAT ('           B.  Print Results to Disk File')
 928  FORMAT ('           C.  Restart Program')
 929  FORMAT ('           D.  Return to DOS')
 930  FORMAT ('       Select Desired Option       ---> '\)
 931  FORMAT (2X,I2,'.  Enter Crit. Reach Name')
 932  FORMAT ('       [* Up to 25 Characters *]   ---> '\)
 933  FORMAT (2X,I2,'.  Enter Save File Name')
 934  FORMAT ('       [* Path Spec. Optional *]   ---> '\)
 935  FORMAT ('Critical Reach:   '\)
 936  FORMAT (2X,I2,'.  Program Terminated Normally After ',I2,' Run(s)
     1')
C
C     ---------------------------------------------------------------------------
C
 1000 INCR2=INCR2+1
      WRITE (*,936)INCR2,KOUNT
      WRITE (*,900)
      END
```

APPENDIX 4: TABLES OF EMBRYO SURVIVAL

Table A.1.--Relationships between percent fine sediments individual and embryo survival in individual egg baskets with predictions based on relationships used in FISHSED, Poverty Flat.

1986-87			1987-88		
	Survival			Survival	
Actual Fines (%)	Predicted	Observed	Actual Fines (%)	Predicted	Observed
18.4	81	91	20.1		5
13.9	86	71	28.6		0
13.8	86	76	13.4		97
4.8	91	92	11.4		5
7.3	90	12	16.6		95
4.7	91	11	8.5		44
21.6	75	53	26.8		15
10.1	89	15	26.4		8
18.4	81	73	19.0		93
11.6	88	0	19.9		52
13.7	86	3	15.2		56
15.5	85	37	15.6		26
20.1	78	4	17.8		89
19.9	79	0	17.0		85
19.2	80	49	14.9		52
15.3	85	37	13.3		36
11.1	88	79	11.1		91
12.2	88	0	11.6		75
17.5	82	87	17.6		79
11.7	88	65	18.1		12
----	--	--	37.7		0
----	--	--	6.1		85
----	--	--	21.2		7
----	--	--	27.4		0
----	--	--	53.6		0
----	--	--	21.3		37
----	--	--	16.4		78
----	--	--	18.1		77
----	--	--	23.9		70
Averages					
14.1	86	42	19.6		47

Table A.2.--Relationships between percent fine sediments individual and embryo survival in individual egg baskets with predictions based on relationships used in FISHSED, North Fork Red River.

1986-87			1987-88		
Actual Fines (%)	Survival		Actual Fines (%)	Survival	
	Predicted	Observed		Predicted	Observed
2.2	91.6	67.4			
10.8	88.6	24.0			
1.7	91.7	23.3			
19.8	78.7	47.3			
28.6	56.3	2.0			
21.2	75.9	5.8			
36.6	30.3	0.0			
34.3	37.6	34.7			
25.8	64.8	67.3			
21.5	65.7	44.0			
27.0	61.5	34.7			
25.8	64.8	98.0			
11.6	88.0	77.3			
14.3	85.9	59.3			
15.6	84.6	77.3			
19.9	78.6	64.4			
25.9	64.6	90.0			
12.3	87.6	60.0			
Averages					
19.7	78.8	48.7			